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BRL

MEMORANDUM REPORT NO. 1192

FEBRUARY 1959

THE EFFECT OF SYSTEM DESIGN CHARACTERISTICS ON FIRST ROUND HITTING PROBABILITY OF TANK FIRED PROJECTILES (U)

E. C. CHRISTMAN

Brewer

DEPARTMENT OF THE ARMY PROJECT NO. 503-04-004
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT NO. TB3-1224

BALLISTIC RESEARCH LABORATORIES

ORDNANCE CORPS U.S.A.

ABERDEEN PROVING GROUND, MARYLAND

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ECChristman/gt
Aberdeen Proving Ground, Md.
February 1959

THE EFFECT OF SYSTEM DESIGN CHARACTERISTICS ON FIRST ROUND HITTING PROBABILITY OF TANK FIRED PROJECTILES (U)

(UNCLASSIFIED) ABSTRACT

Graphs showing the first round probability of hitting a stationary vertical 7.5' by 7.5' target under quasi-combat conditions are presented for a wide range of conventional tank armament system characteristics. These results provide a way of rapidly estimating the first round hitting capabilities of various systems and are used in studying the relative effect of various projectile and fire control design parameters.

(UNCLASSIFIED) INTRODUCTION

A prime factor insofar as the effectiveness of any tank gun-ammunition-fire control system is concerned is the system's ability to provide a target hit. In any particular direct fire situation, however, the probability of hitting a given target generally varies from one round to the next. Experience has indicated that it is appropriate to divide hitting probability into three categories with respect to rounds fired from the same position; these are the probability of hitting on first rounds, the probability of hitting given a miss on each previous round, and the probability of hitting given a hit on a previous round.

Assuming, for the moment, that the initial round has been fired, the errors present on subsequent shots are those which vary from round to round and those which are incident to the observation and adjustment of fire. It appears that the ability to accurately observe and adjust fire is relatively poor on rounds fired subsequent to the first round but prior to the first hit. Studies are currently being conducted by the BRL to investigate the relationships between impact sensing, fire adjustment, and hitting probability. For this reason, probability of hitting given a miss on each previous round is not considered further in this report.

If a target hit occurs, however, the ability to observe the hit and make minor adjustments is apparently good. The probability of hitting given a hit on a previous round seems to depend primarily on those errors which vary from round to round, the most important being that called "round-to-round dispersion". It is believed possible to obtain good predictions of the probability of hitting given a hit by assuming "round-to-round dispersion" to be the dominant error source. Since the direct effect of other system design parameters is relatively minor, probability of hitting given a hit on a previous round is also not considered further in this study.

The present report then is concerned solely with first rounds, more specifically, with the probability of hitting a stationary vertical 7.5' by 7.5' target, under quasi-combat conditions, with the first round fired. Probability of hitting on first rounds is affected not only by errors which vary from round to round but also by fixed system biases and by biases which vary from firing position to firing position or zeroing operation to zeroing operation. The effect of these errors and biases on first round hitting probability is dependent to a considerable extent on the characteristics of the armament system. The results presented in this report are intended to make possible rapid estimation of the first round hitting capabilities of conventional tank armament systems and to indicate how first round hitting capabilities are affected by varying projectile and fire control design parameters.

It is appropriate, at this point, to indicate briefly what is meant by "quasi-combat". Frankford Arsenal Report R-1380A* defines several test

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* Confidential, February 1958, "Fire Control Studies, Tank Gunnery Evaluation," by Harold Brodkin.

categories and, for each category, explicitly describes the conditions under which tests should be carried out. For purposes of weapon effectiveness evaluation, as opposed to proof and development tests, hitting probabilities should be computed for conditions which are as representative of combat conditions as possible. Such a set of conditions is defined in the Frankford report and designated therein as Quasi-combat (or Quasi-Battle) conditions. These conditions are used as the basis for all hitting probability computations in the present study.

(UNCLASSIFIED) GENERAL APPROACH

The general approach used in the present study basically involves computing first round hitting probabilities against a stationary vertical 7.5' by 7.5' target under quasi-combat conditions for selected combinations of system design parameters. On the basis of these results, the manner in which first round hitting probabilities depend on system characteristics is discussed.

([redacted]) FACTORS AFFECTING FIRST ROUND HITTING PROBABILITY

Of the error sources affecting hitting probability under quasi-combat conditions, some vary with fire control system, some with projectile design parameters, and some with a combination of these factors. Since fire control systems and projectile parameters are the factors which may be controlled in design, these are considered of principal interest in the present study.

Three fire control systems are considered. The simplest, designated as system A, consists of a telescope with ballistic reticle and utilizes visual range estimation. A second system, system B, is the one used in the M48 tank and includes an optical range finder, a periscope, an automatic ballistic drive, and a computer. It is roughly representative of systems utilizing optical range determination. The third system, system C, is a concept system which would include an accurate range measuring device, a periscope, an automatic ballistic drive and a computer and would compensate for cant, drift, and parallax.

The three systems vary in the type of ranging error introduced. System A produces a standard error in range whose percent of true range is constant for all ranges, whereas system C produces a standard error in range which remains constant for all ranges of interest. The range standard error of optical range finders, as that in system B, increases as the square of the range and is usually stated in terms of Units of Error (UOE).

The standard deviation of fire control instrument errors is assumed to be .3 mil in elevation for each of the three systems but to vary in deflection, being .075 mil for the simple system A and .2 mil for the more complex systems B and C. These values are not quite in agreement with the values suggested in Frankford Report R-1380A but are believed to be representative of what is actually achieved in production.

The cant corrector incorporated in system C would compensate for cant, which may be an important source of error in the other systems. The parallax and drift biases, present in each of the three systems, also would be compensated for in system C. The parallax error results from the offset between the gun tube and the optical axis of the direct fire sight and is thus dependent on the dimensions of the system. Although the magnitudes of parallax error used for systems A and B are based on the measurements of particular systems, they are essentially applicable to other systems of basically similar types. The error due to drift is defined as the difference between the drift at the target range of the projectile fired for effect and the drift at the zeroing range of the zeroing projectile. For systems A and B, the magnitude used for the bias due to drift increases from zero at the zeroing range at the rate of about .1 mil per 500 yards. The zeroing range is taken to be 1500 yards throughout the present study.

As for projectile design parameters, projectile type, weight, diameter, form factor, and muzzle velocity all affect hitting probability. Each of these affects time of flight and hence those error sources whose magnitudes are in some way related to time of flight. Weight, diameter, and form factor combine to give the ballistic coefficient, the factor on which time of flight and superelevation depend.* Siacci functions were used to compute time of flight and superelevation data** for all combinations of the following parameters:

Muzzle velocity: 1000, 2000, 3000, 4000, 5000 feet per second

Ballistic coefficient: 1.0, 1.3, 1.6, 1.9, 4.0

Such computations were made for each of three standard projectile types, namely, Types 1, 2 and 8. High drag, non-streamlined projectiles fall in Type 1. Streamlined, boat-tailed projectiles are approximated by Type 2, which represents the greatest practical drag reduction. Type 8 is an intermediate group consisting of streamlined, square-tailed projectiles. For reference purposes, a tabulation indicating the muzzle velocity, type, weight and ballistic coefficient of projectiles developed for the defeat of armor is given in Appendix A.

An additional projectile parameter needs to be included, namely, round-to-round dispersion. Round to round standard deviation values of .15, .30, .45 and .60 mil are considered in this study.

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* More explicitly, $C = w/id^2$, where w is weight in pounds, d is diameter in inches, and i is form factor.

** Time of flight and superelevation data constitute necessary input information in the computation of first round hitting probabilities.

Tables I and II show the sources of horizontal and vertical error considered in computing first round hitting probability; the tables also show the magnitudes of these errors and an example of their resulting contribution to net dispersion. The values shown in the right hand column apply to one particular combination of factors and are shown simply to indicate the relative magnitudes of the errors at the target due to a particular error source. Errors are classified as to whether they are fixed biases, variable biases, or random errors. Dispersions are given in terms of their standard deviation (σ), rather than probable error. The error sources listed are those described in Frankford Arsenal Report R-1380A. The magnitudes are substantially in agreement with those of R-1380A; however, in several instances error magnitudes slightly different from those of R-1380A were used. This occurred in part because calculations were begun prior to publication of R-1380A and in part because they were thought to be more appropriate.

TABLE I

HORIZONTAL ERRORS ON FIRST ROUNDS - QUASI-COMBAT CONDITIONS

Source	Magnitude of Source			Horizontal Errors (₥) at 2000 yds Range Due to Source Conditions: M. V. = 3000 fps; C = 1.00; σ_r = .30 ₥; zeroed at 1500 yds		
	Fire Control			Fire Control		
	A	B	C	A	B	C
Fixed Biases						
Drift	.1 ₥/500 yds for A & B only, 0 for C			.100	.100	0
Fire Control	0	0	0	0	0	0
Jump, mean	0	0	0	0	0	0
Parallax	1.25 ft	2 ft	0	.070	.111	0
Net Fixed Biases				.170	.211	0
				Contribution to Horizontal Net Dispersion		
Variable Biases						
Cant	89 ₥	89 ₥	0	1.967	1.967	0
Fire Control	.075 ₥	.2 ₥	.2 ₥	.075	.200	.200
Jump Variation	.25 ₥	.25 ₥	.25 ₥	.250	.250	.250
Wind, cross	11 fps	11 fps	11 fps	1.650	1.650	1.650
Zeroing						
Cant	22 ₥	22 ₥	0	.304	.304	0
Fire Control	.075 ₥	.075 ₥	.075 ₥	.075	.075	.075
Group center of impact	$\sigma_r/\sqrt{5}$	$\sigma_r/\sqrt{5}$	$\sigma_r/\sqrt{5}$	.067	.067	.067
Jump variation	.25 ₥	.25 ₥	.25 ₥	.250	.250	.250
Observation of C. I.	.05 ₥	.05 ₥	.05 ₥	.050	.050	.050
Wind, cross	11 fps	11 fps	11 fps	1.136	1.136	1.136
Random Errors						
Round to Round Dispersion	.15, .30, .45, .60 ₥ for A, B, C			.300	.300	.300
Laying Error	1.0 ft	1.0 ft	1.0 ft	.167	.167	.167
Net Dispersion (σ_x)				2.872	2.878	2.079

TABLE II

VERTICAL ERRORS ON FIRST ROUNDS - QUASI BATTLE CONDITIONS

Source	Magnitude of Source			Vertical Errors (m̸) at 2000 yds Due to Source Conditions: M. V. = 3000 fps; C = 1.00; σ_r = .30 m̸; zeroed at 1500 yds		
	Fire Control			Fire Control		
	A	B	C	A	B	C
Fixed Biases						
Fire Control	0	0	0	0	0	0
Jump	0	0	0	0	0	0
Parallax (at 0 range)	.5 ft	2.0 ft	0	.027	.111	0
Range estimation	0	0	0	0	0	0
Net Fixed Bias				.027	.111	0
Variable Biases				Contribution to Vertical Net Dispersion		
Jump Variation	.31 m̸	.31 m̸	.31 m̸	.310	.310	.310
Fire Control	.30 m̸	.30 m̸	.30 m̸	.300	.300	.300
Muzzle Velocity(lot to lot)	22 fps	22 fps	22 fps	.523	.523	.523
Range estimation	.21 R	6UOE	12 yds	4.739	.718	.138
Zeroing						
Fire Control	.075 m̸	.075 m̸	.075 m̸	.075	.075	.075
Group C.I.	$\sigma_r/\sqrt{5}$	$\sigma_r/\sqrt{5}$	$\sigma_r/\sqrt{5}$	.067	.067	.067
Jump	.31 m̸	.31 m̸	.31 m̸	.310	.310	.310
Muzzle Velocity(lot to lot)	22 fps	22 fps	22 fps	.279	.279	.279
Observation of C. I.	.05 m̸	.05 m̸	.05 m̸	.050	.050	.050
Range estimation	.015 R	.015R	12 yds	.205	.205	.110
Random Errors						
Round to round dispersion	.15, .30, .45, .60 m̸ for A, B, C			.300	.300	.300
Laying error	1.0 ft	1.0 ft	1.0 ft	.167	.167	.167
Net dispersion (σ_y)				4.825	1.155	.899

([redacted]) RESULTS AND DISCUSSION

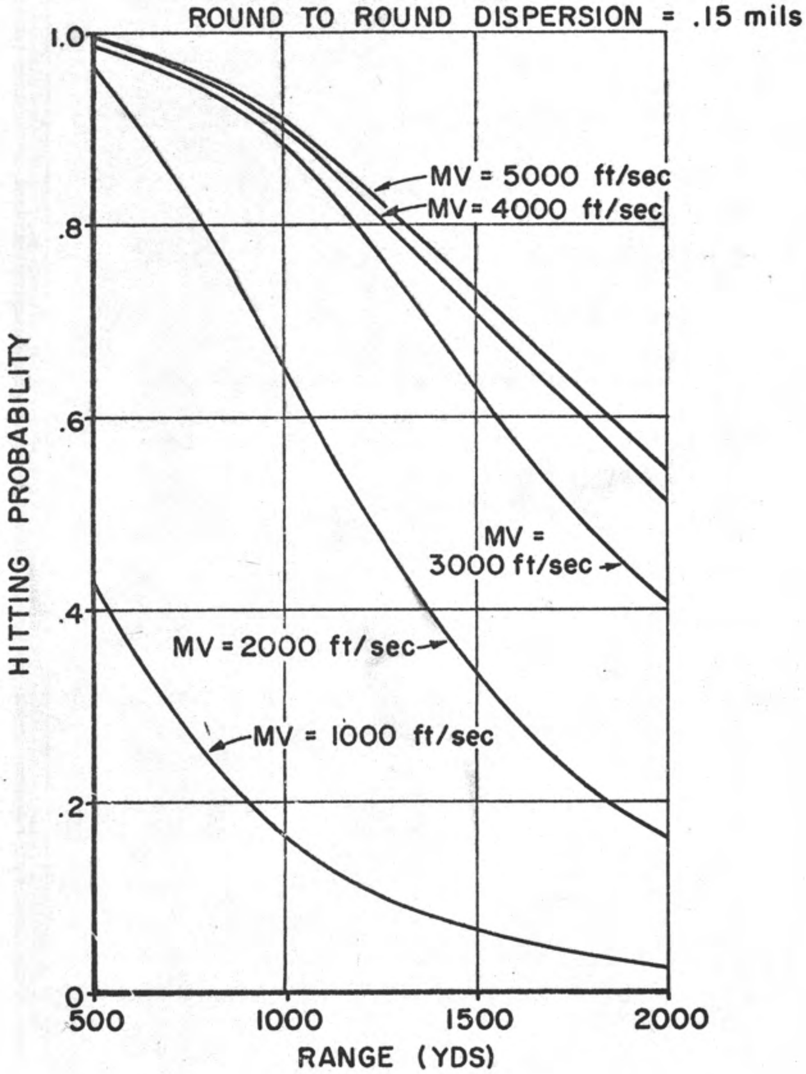
A set of 48 pages showing in graphical form all the first round hitting probabilities computed is contained in Appendix B. These are arranged in three groups of 16 pages, one group for each of the projectile types 1, 2, and 8. Within each group, results are arranged according to target range and round to round dispersion. Each page contains, for a specified combination of target range and round to round dispersion, sets of curves showing hitting probabilities as a function of muzzle velocity, ballistic coefficient, and fire control system.

The preceding results can be utilized in various ways. One obvious application, of course, is to use them in estimating first round hitting probabilities for different systems, whether system characteristics are definitely known or can only be estimated. As another application, the hitting probabilities in Appendix B can be plotted in alternate ways to illustrate more explicitly the effect of certain factors. The following are some examples showing how this can be done; it is believed that the examples selected should help clarify the principal points that may be of interest.

In figure 1 hitting probability has been plotted against range, for systems with the indicated characteristics, to illustrate the great falloff in hitting probability occurring at the longer ranges. The dominant errors causing this falloff are those of range determination, cant, and cross wind. At short range the more important errors are the fixed biases and the random errors associated with laying the gun.

FIGURE 1
EFFECT OF RANGE ON
FIRST ROUND PROBABILITY OF HITTING
A 7.5' X 7.5' TARGET

CONDITIONS:
FIRE CONTROL SYSTEM C
PROJECTILE TYPE I
BALLISTIC COEFFICIENT = 1.6
ROUND TO ROUND DISPERSION = .15 mils



The influence of fire control system on first round hitting probability is readily indicated by the curves in Appendix B. Each of the three fire control systems affects first round hitting probability in a characteristic way. In all cases hitting probability levels off as muzzle velocity increases, but, for the complex system C, this leveling off occurs at a much lower velocity than for the other systems, the latter effect being due primarily to the very low range determination error and the elimination of the cant error. Both of these errors are dependent on time of flight or superelevation and tend to be quite large, particularly at the lower velocities. System C, therefore, affords better first round accuracy than the other two systems in the low velocity range and has little need for a high velocity projectile. The complex systems B and C also provide greater accuracy than system A at the longer ranges. Here again the reduction of errors dependent on time of flight is responsible, since these errors are quite large at long range.

Casual inspection of the graphs shows that, of the three fire control systems, system C is most affected by variations in ballistic coefficient. With the other systems, the natural degrading effect of decreased ballistic coefficient is dulled by a multiplicity of other errors.

It may be noted that system A, generally less accurate than B, is more accurate at 500 yards range. System A has a smaller parallax bias than B, as a result of the nearness of the telescope to the gun, and the large bias of system B at this short range degrades the probability of hitting more than the optical range determination equipment improves the probability of hitting.

The effect of round to round dispersion is generally overshadowed by the presence of other errors. However, if the net error resulting from other error sources is small, round to round dispersion may form a major part of the total error present and assume more importance. These conditions would exist for a high muzzle velocity round and/or fire control system C; the effect is illustrated in Figure 2. In general, the random round to round dispersion error has its greatest effect at intermediate target ranges.

Varying projectile design parameters in such a way as to change ballistic coefficient has only a moderate effect for streamlined projectiles or the least complex fire control system. For a Type 1 projectile and/or the more complex fire control systems, the effect is considerably greater. As an example of how the hitting probability graphs may be used in estimating the effect of design changes, consider a 90 mm projectile having a ballistic coefficient of 1.0, fired from the M41 gun at 4060 ft/sec. Assume a round to round dispersion of .15 mil. If the ballistic coefficient is increased to values of 1.3, 1.6, 1.9, and 4.0 by increasing the projectile weight and keeping form factor and propelling charge constant, the muzzle velocity would decrease and hitting probability would

FIGURE 2
EFFECT OF ROUND TO ROUND DISPERSION ON FIRST ROUND PROBABILITY OF HITTING A 7.5' X 7.5' TARGET

CONDITIONS:
FIRE CONTROL SYSTEM C
PROJECTILE TYPE 1
BALLISTIC COEFFICIENT = 1.0
RANGE = 1000 YARDS

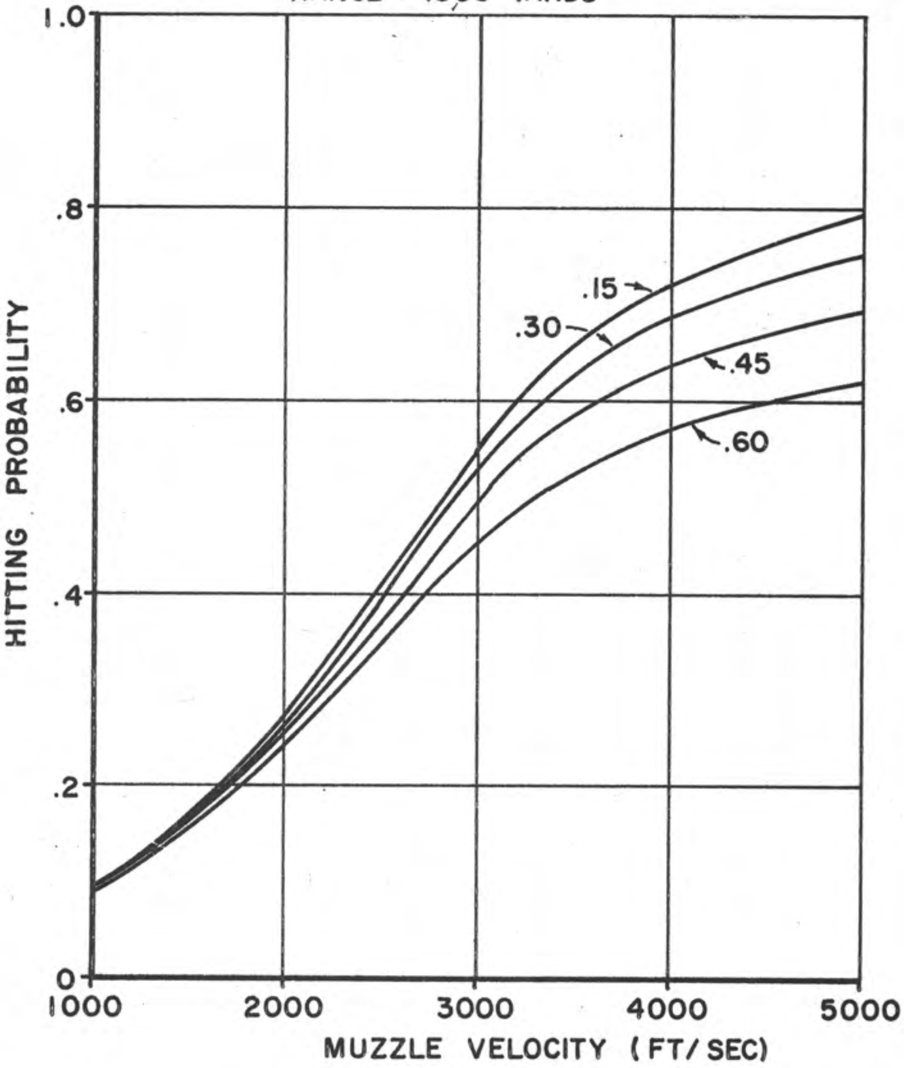
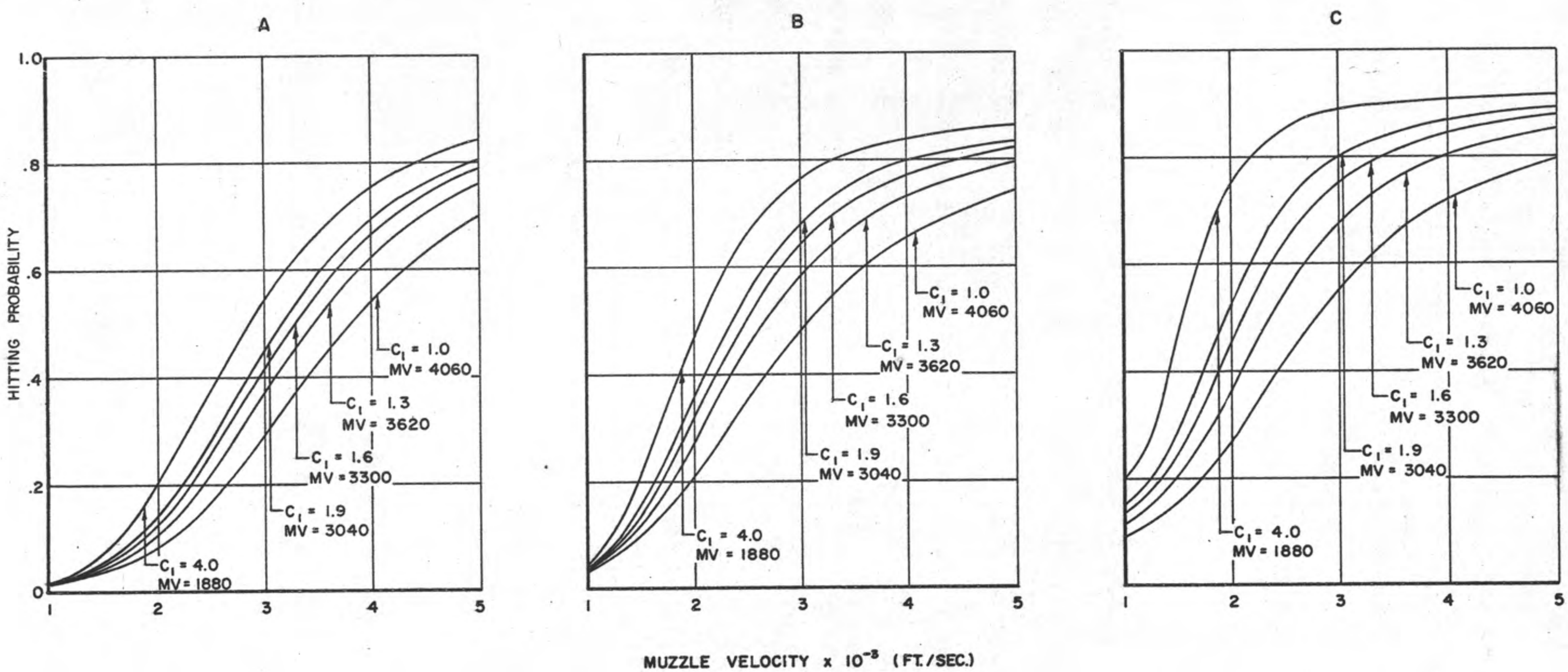


FIGURE 3
EFFECT OF VARYING BALLISTIC COEFFICIENT BY CHANGING PROJECTILE WEIGHT.

PROJECTILE TYPE I
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 ⌀



NOTE : INCREASING WEIGHT WILL INCREASE BALLISTIC COEFFICIENT AND DECREASE MUZZLE VELOCITY.

change as shown in Figure 3. Note that with fire control system A the original projectile (C_1=1.0 and MV=4060 ft/sec) gives the highest hitting probability. For fire control B a muzzle velocity of about 3300 ft/sec becomes optimum; for fire control C about 3000 ft/sec is best so far as hitting probability is concerned. In the case of fire control systems B and C it is more profitable to increase ballistic coefficient than muzzle velocity. The lower velocity round used with a complex fire control system is potentially more desirable. Of course, its additional weight might also permit increasing terminal effectiveness.

The manner in which muzzle velocity and ballistic coefficient may be varied in maintaining a constant hitting probability at a given range, assuming a low round to round dispersion and a high drag projectile type, is indicated in Figure 4. For projectiles having high muzzle velocity or high round to round dispersion, hitting probability tends to be less responsive to changes in ballistic coefficient. The degree to which high round to round dispersion can nullify the effects of high ballistic coefficient may be observed from Figure 5.

FIGURE 4
INTERACTION OF MUZZLE VELOCITY AND BALLISTIC COEFFICIENT IN MAINTAINING CONSTANT HITTING PROBABILITY

CONDITIONS:
- FIRE CONTROL SYSTEM C
- PROJECTILE TYPE I
- ROUND TO ROUND DISPERSION = .15 mils
- RANGE = 1000 yards
- TARGET = 7.5' X 7.5'

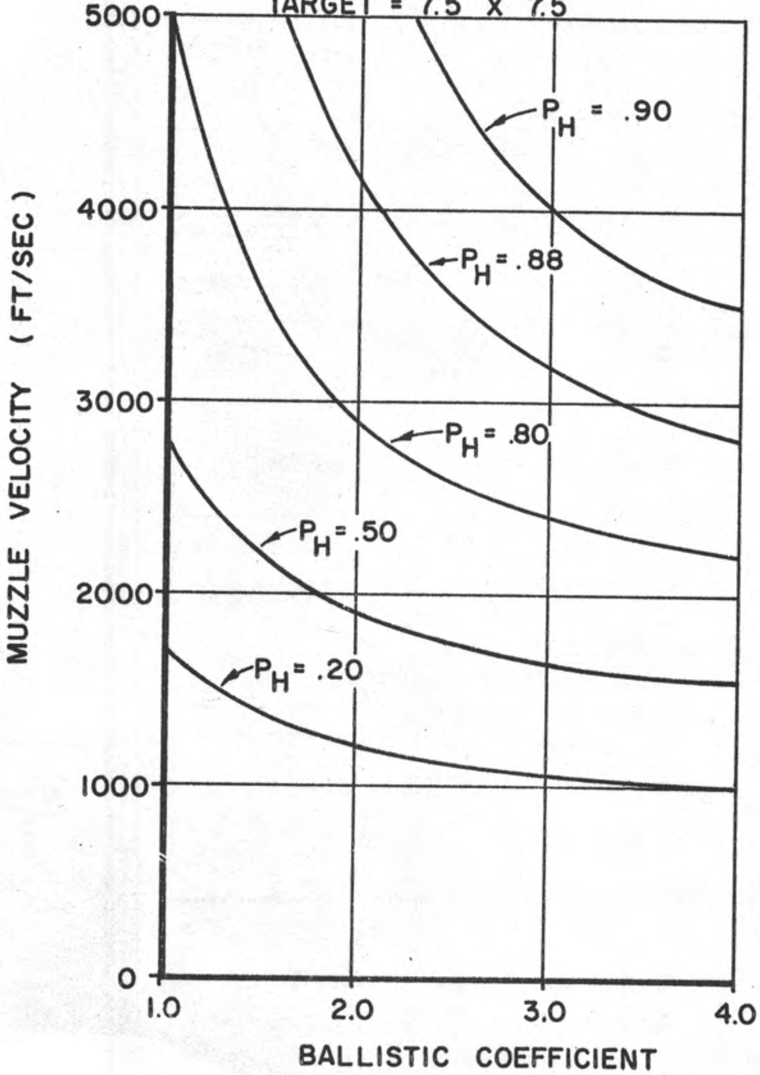
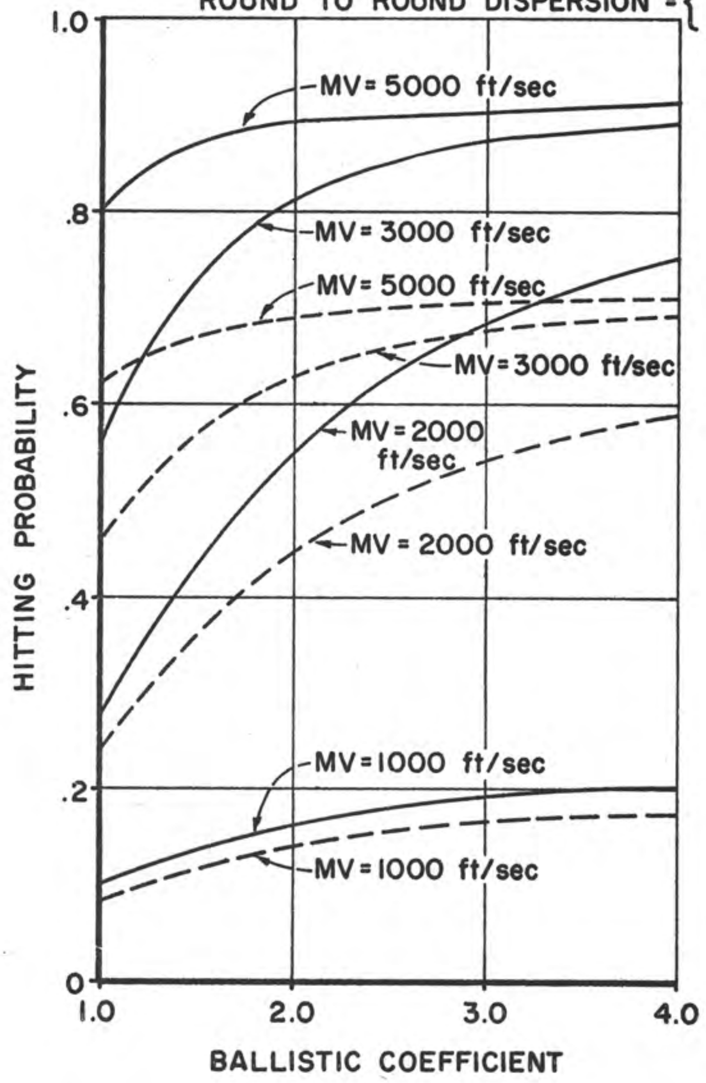


FIGURE 5
EFFECT OF BALLISTIC COEFFICIENT ON FIRST ROUND PROBABILITY OF HITTING A 7 1/2' X 7 1/2' TARGET AS MODIFIED BY MUZZLE VELOCITY AND ROUND TO ROUND DISPERSION

CONDITIONS:
FIRE CONTROL SYSTEM C
PROJECTILE TYPE I
RANGE = 1000 YARDS
ROUND TO ROUND DISPERSION = {.15 mils ——, .60 mils - - -}



(UNCLASSIFIED) SUMMARY

Graphs from which first round hitting probabilities against a stationary vertical 7.5' by 7.5' target, under quasi-combat conditions, can be readily estimated for tank fired projectiles are presented in this report. The manner in which various factors would affect first round hitting probabilities has been briefly discussed.

E. C. Christman

E. C. CHRISTMAN

APPENDIX A

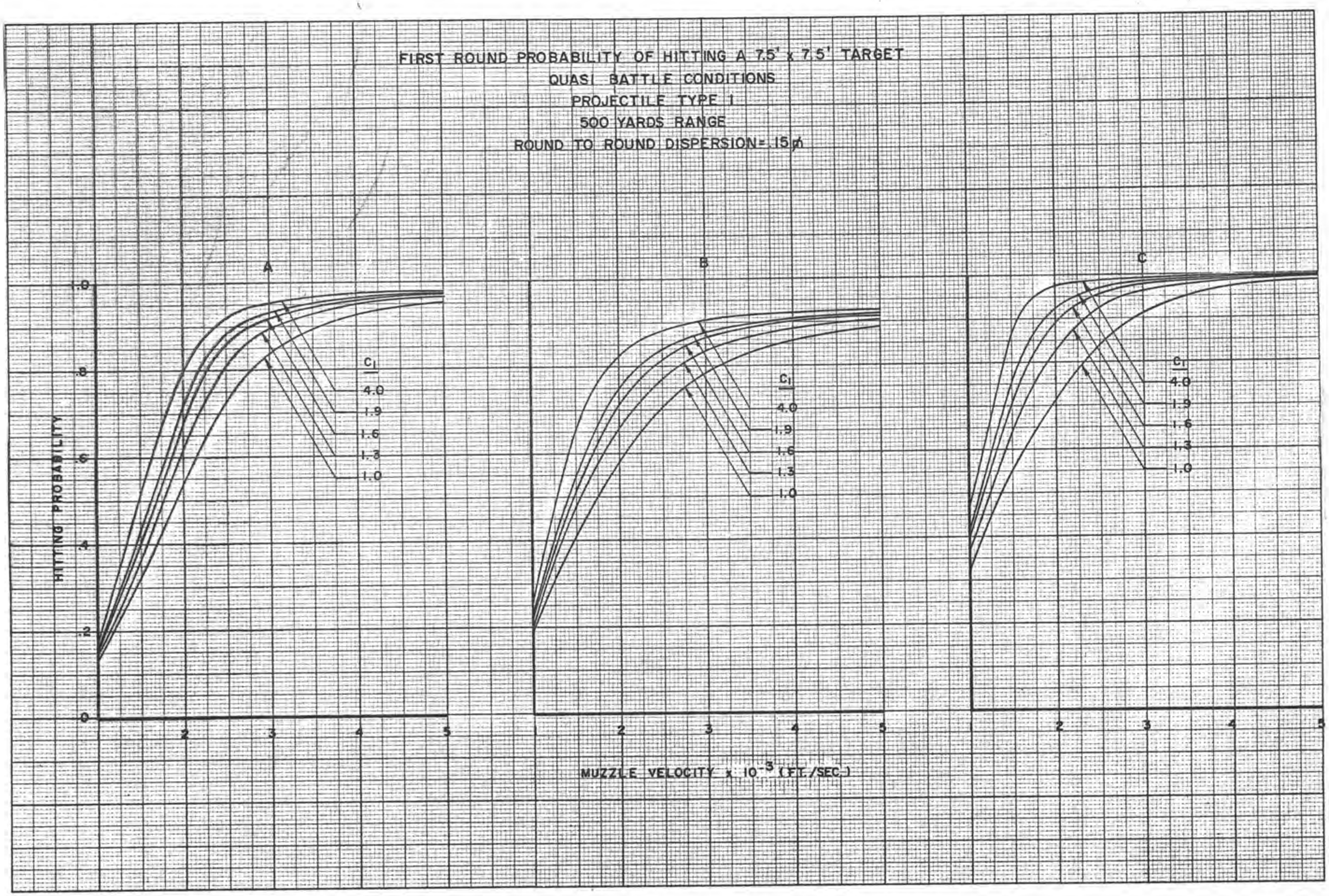
SELECTED BALLISTIC DATA ON PROJECTILES FOR THE DEFEAT OF ARMOR

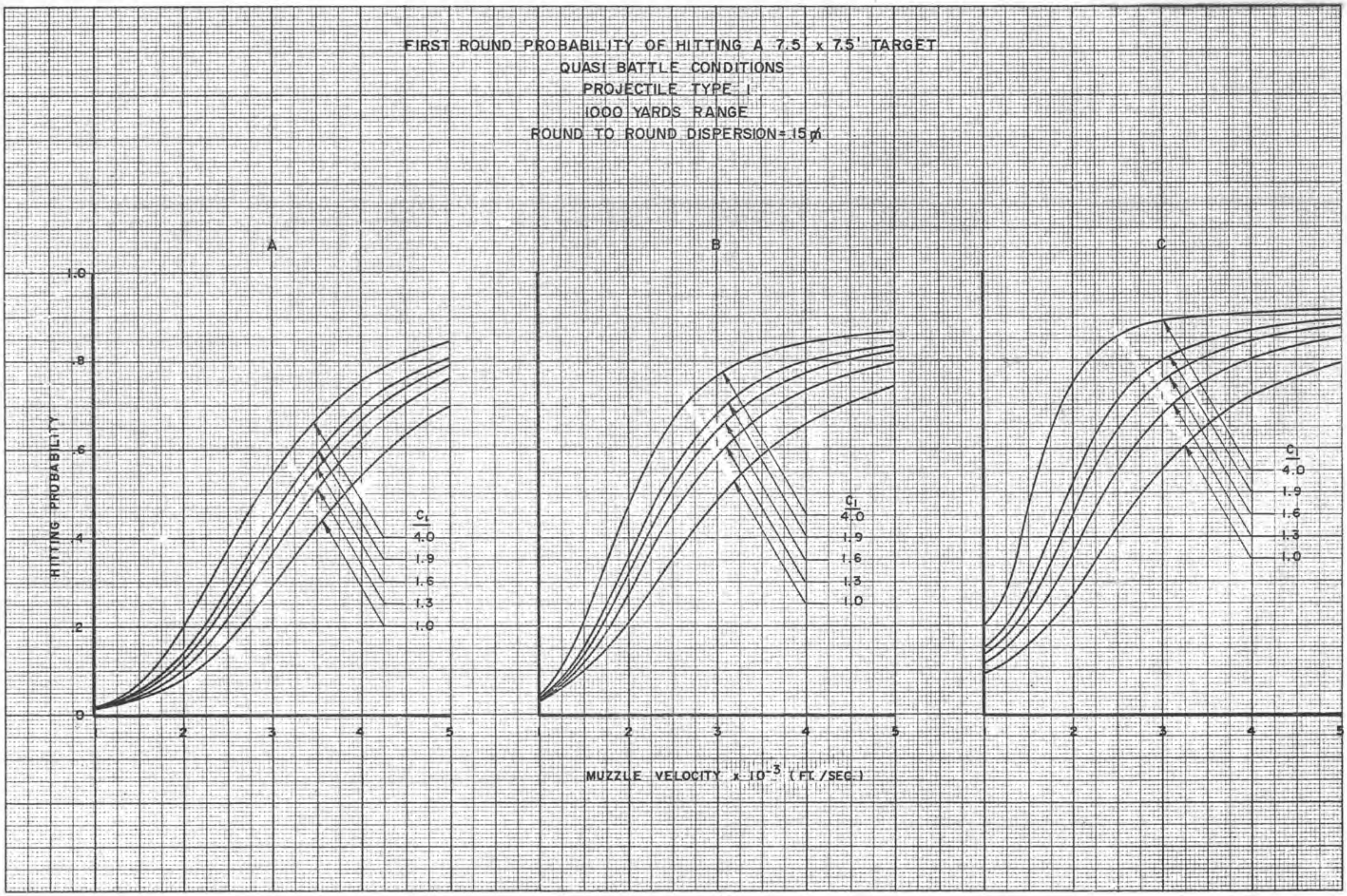
Caliber	Gun	Type	Model	Muzzle Velocity (ft/sec)	In Flight Weight (lbs)	Ballistic Coefficient	Projectile Type
57mm	M1	APC	M86	2700	7.3	1.32	6
75mm	M3, M6	AP	M72	2000	13.9	1.13	5
		AP	M338	2340	13.2	1.34	2.2
		APC	M61A1	2000	14.9	1.735	6
		HEP	T165E11	2400	8.7	1.067	1
76mm	M1A2	AP	M79	2600	15.0	1.59	1
		APC	M62A1	2600	15.4	1.714	6
		HVAP	M93	3400	9.3	.888	8
	M32, M48, T138, T185E1	AP	M339	3200	14.5	1.304	8
		HEAT	T180	3800	7.2	.722	1
		HVAPDS	M331A2	4125	6.2	1.467	8
		HEP	T170E3	2600	10.2	1.193	1
90mm	M3	AP	M77	2700	23.4	1.564	1
		AP	M318A1C	2800	24.1	1.79	6
		APC	M82	2800	24.1	2.16	6
		HEAT	T108E40	2800	16.2	1.97	1
		HVAP	M304	3350	16.8	1.150	8
		HVAP	M332A1	3900	12.4	.826	8
		HEP	T142E5	2600	17.2	1.40	1
	M36, M54, M41	AP	M318A1	3000	24.1	1.61	6.1
		HVAPDS	T137	4100	10.0	1.741	8
		HEAT	T300	4000	12.7	.920	1
	T208	APFSDS	T320	5200	7.8	1.712	2
105mm	T140	AP	T182	3500	35.0	1.665	8
120mm	M58	AP	M358	3500	50.0	2.049	8
		HEAT	T153E8	3900	32.5	1.305	1
		HVAPDS	T102	4750	16.7	2.05	8
		HEP	T143	2700	36	1.682	1
155mm	M2	AP	M112	2745	100	3.00	6
	T180	HEP	T152E5	2600	70	1.58	8

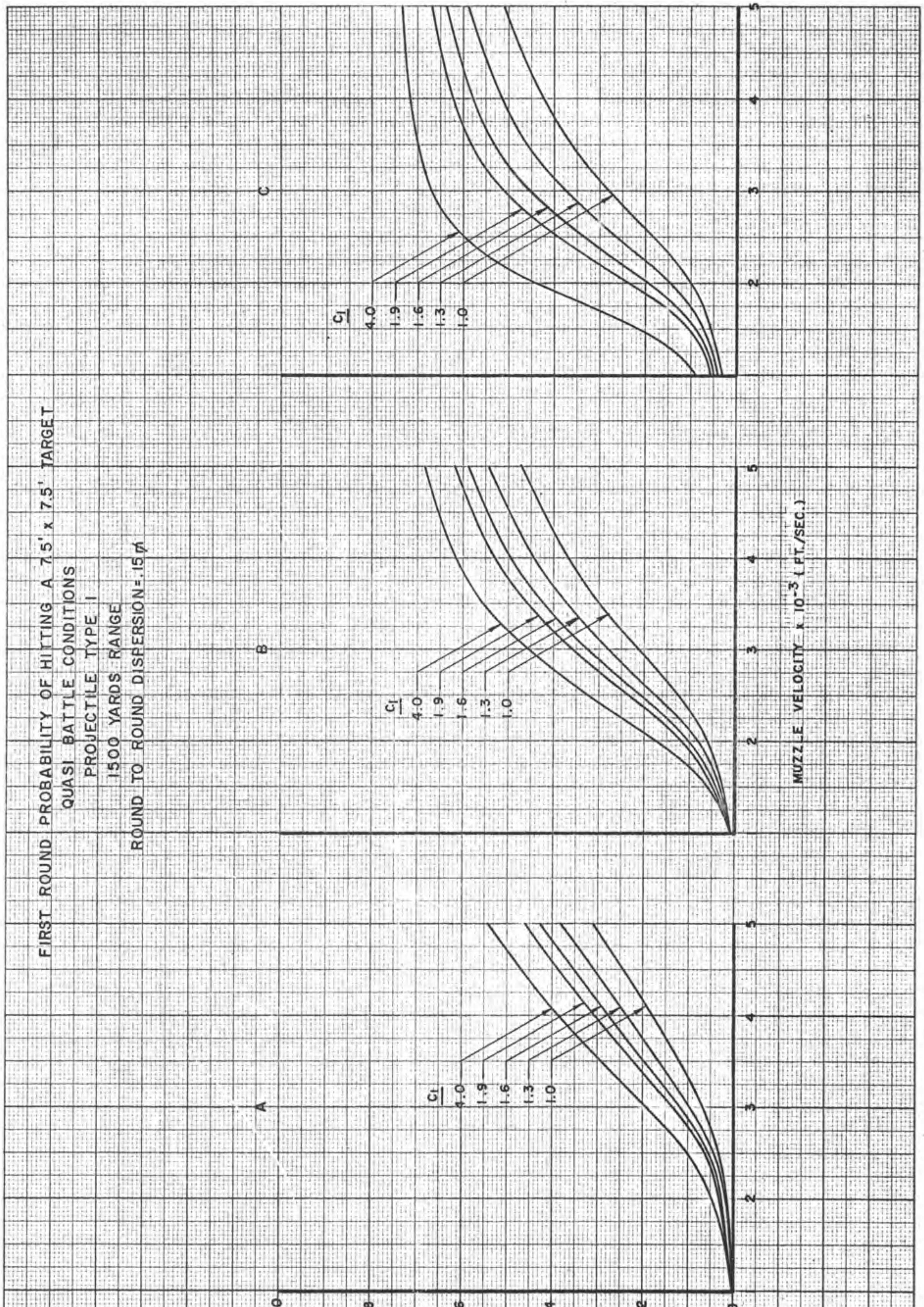
APPENDIX B

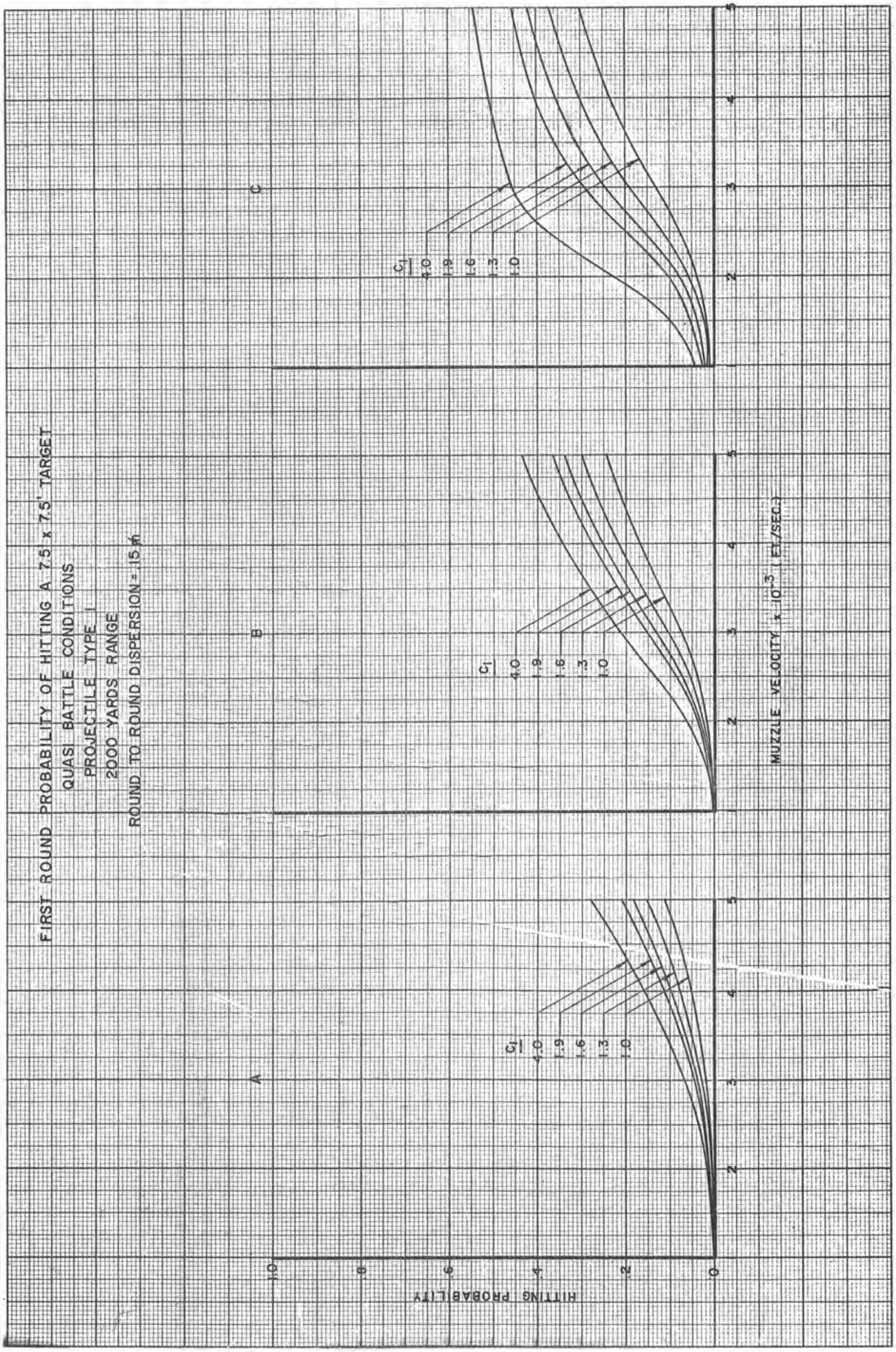
COMPUTED FIRST ROUND HITTING PROBABILITIES

Projectile Type 1

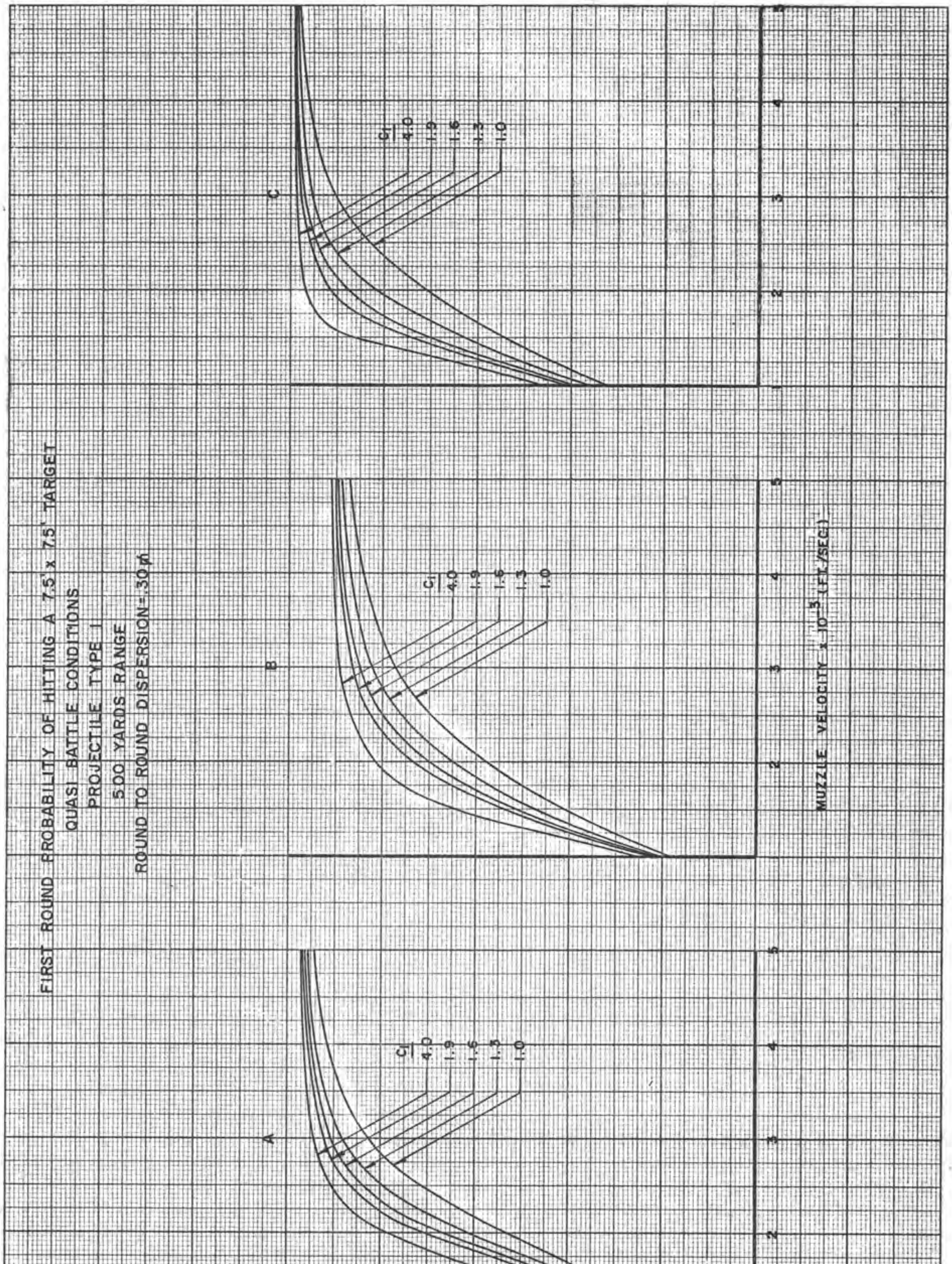

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 1
500 YARDS RANGE
ROUND TO ROUND DISPERSION= 15 ⁄
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

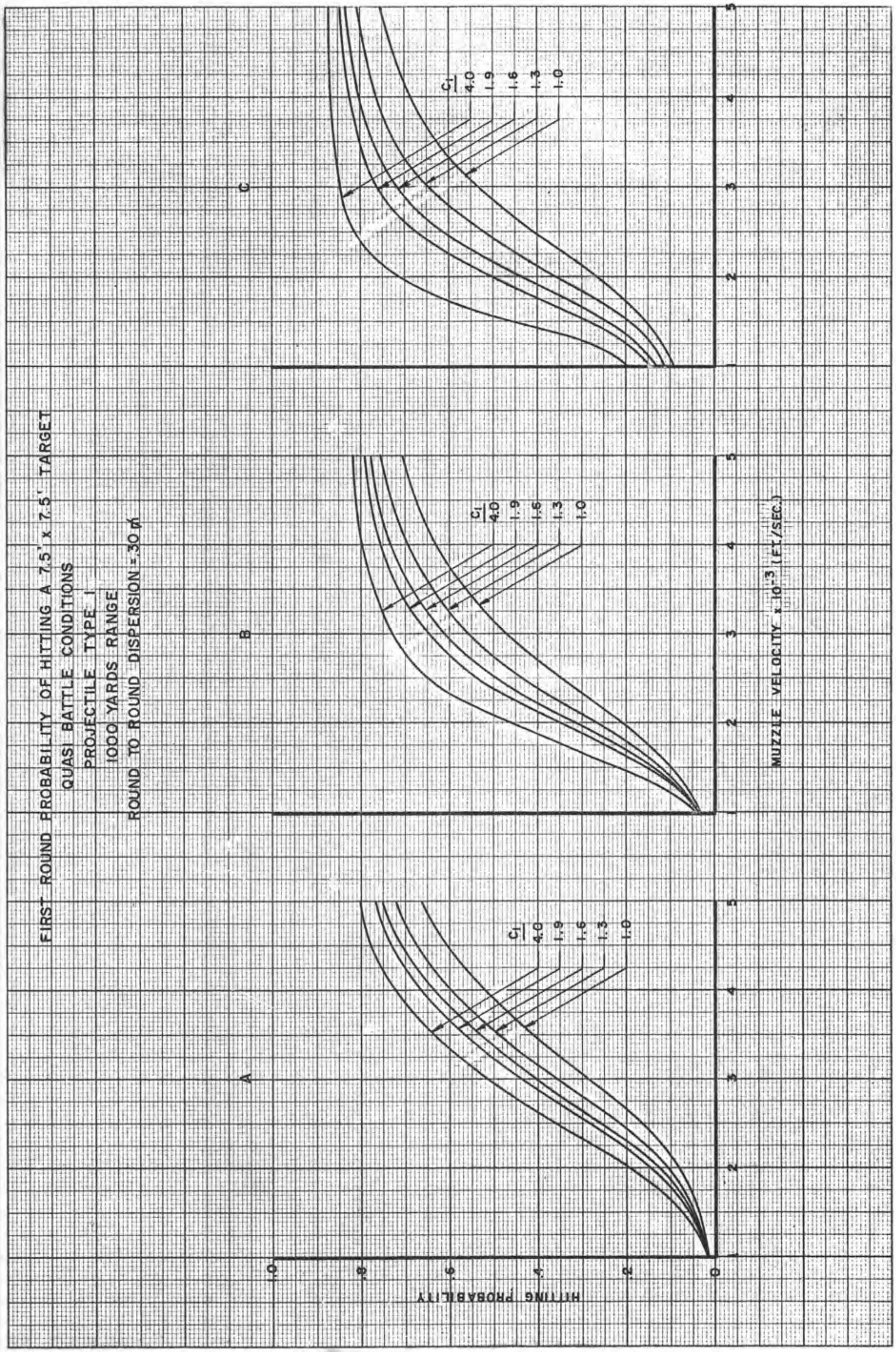

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 mil
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
1
2
3
4
5
C_1
4.0
1.9
1.6
1.3
1.0
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.15
A
B
C
C_I
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)
0
.2
.4
.6
.8
1.0
2
3
4
5

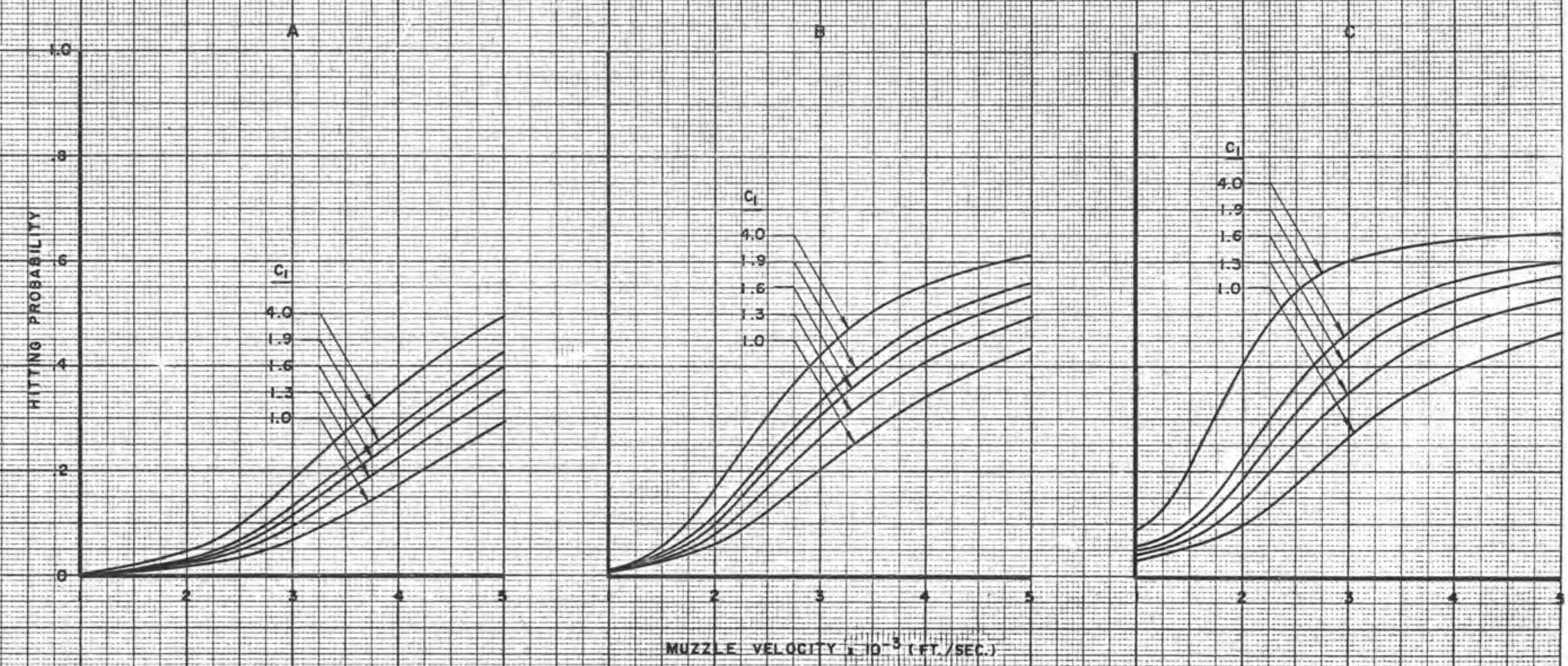


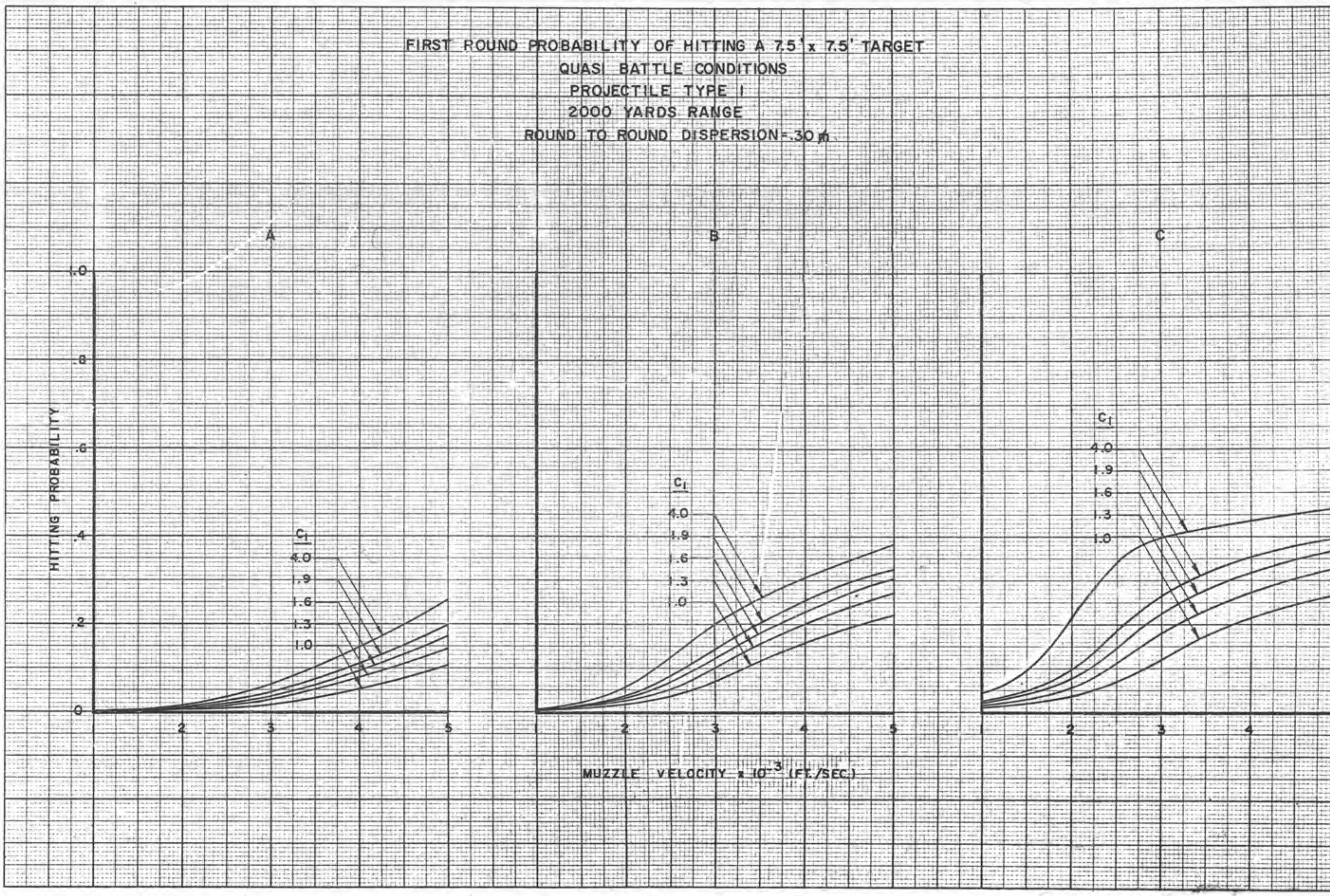
FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 m
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

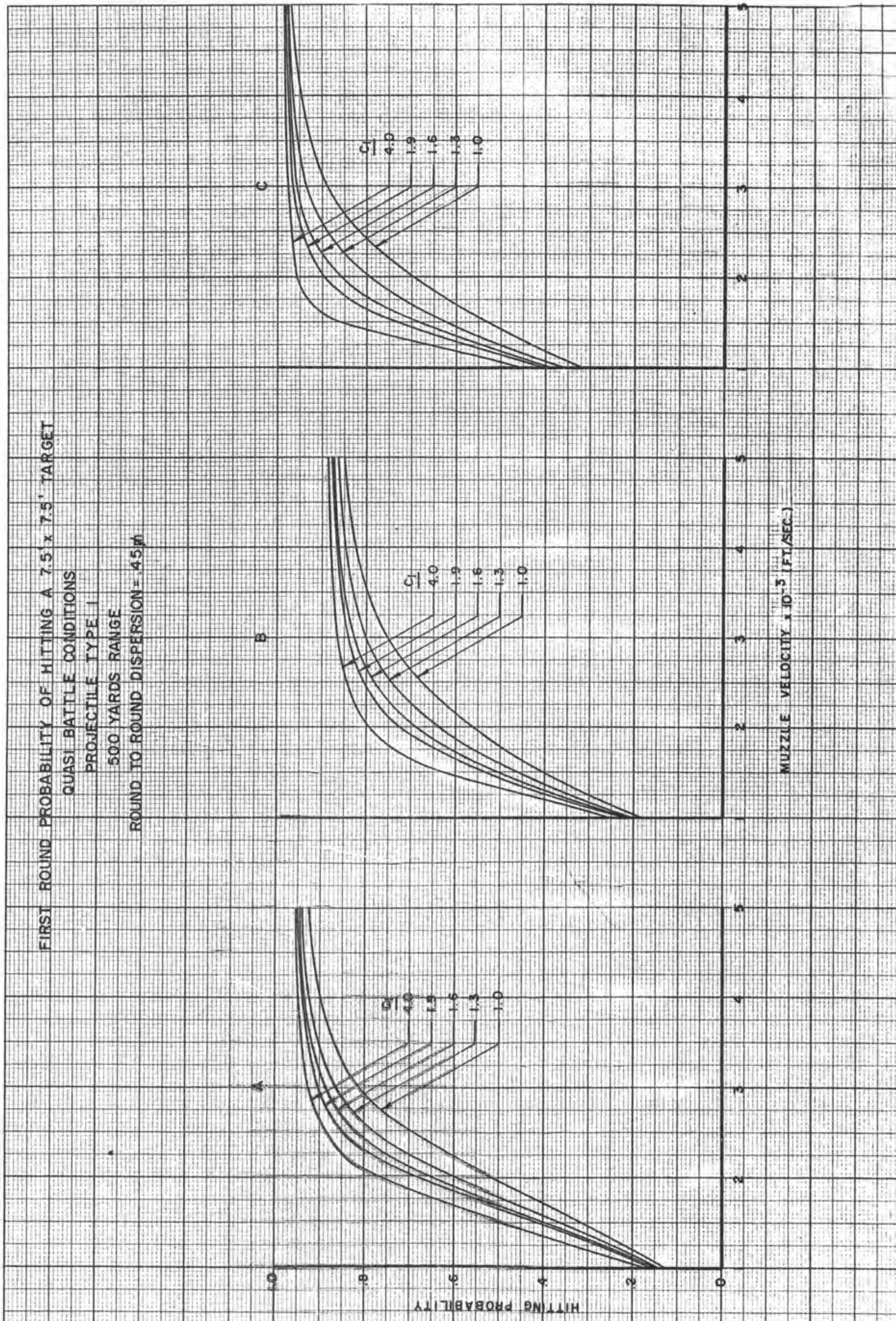

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 1
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

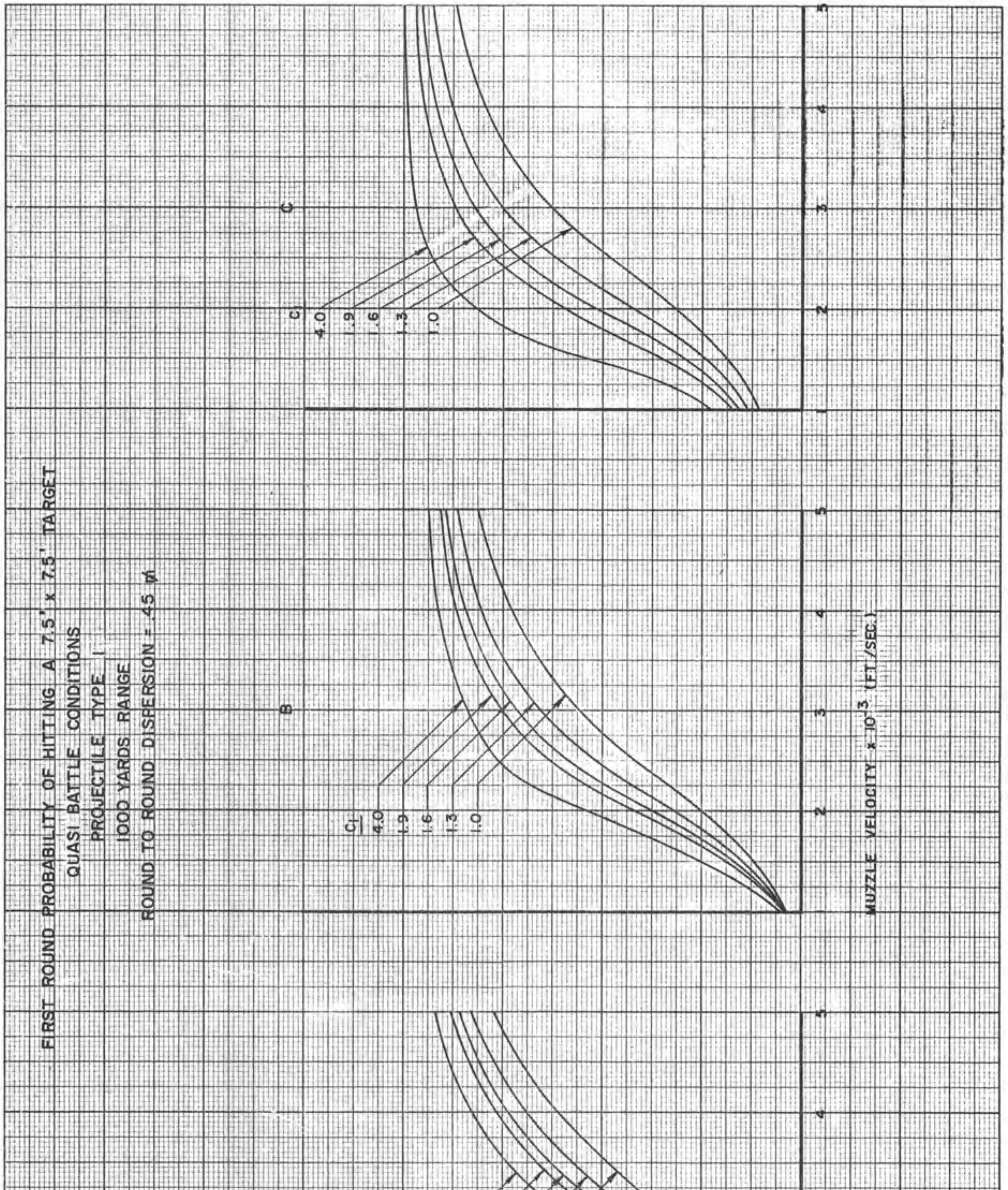
FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1500 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil




FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 m
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C_1
4.0
1.9
1.6
1.3
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .45 mil
A
B
C
HITTING PROBABILITY
MUZZLE VELOCITY x 10^-3 (FT./SEC.)

CONFIDENTIAL



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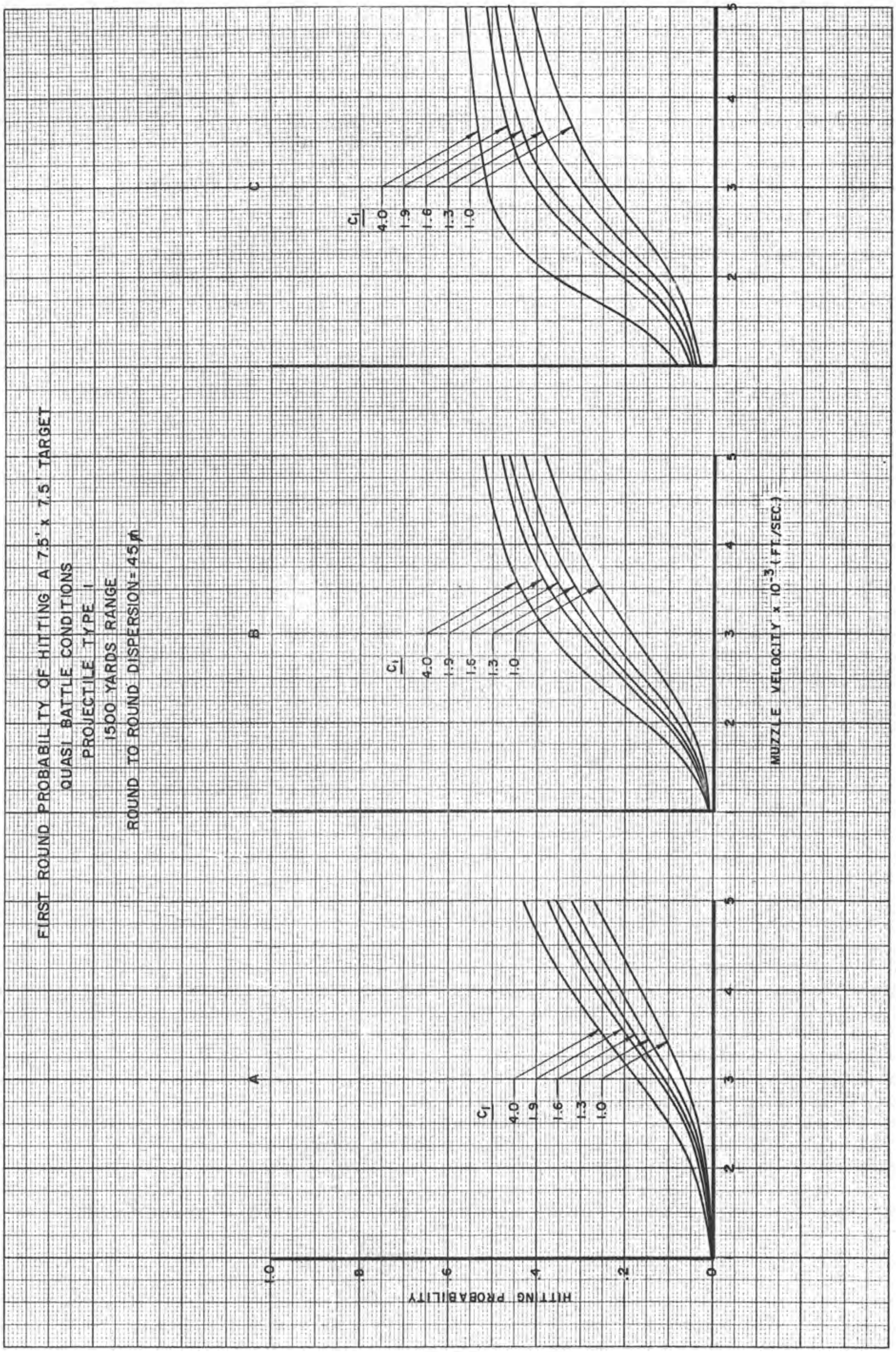
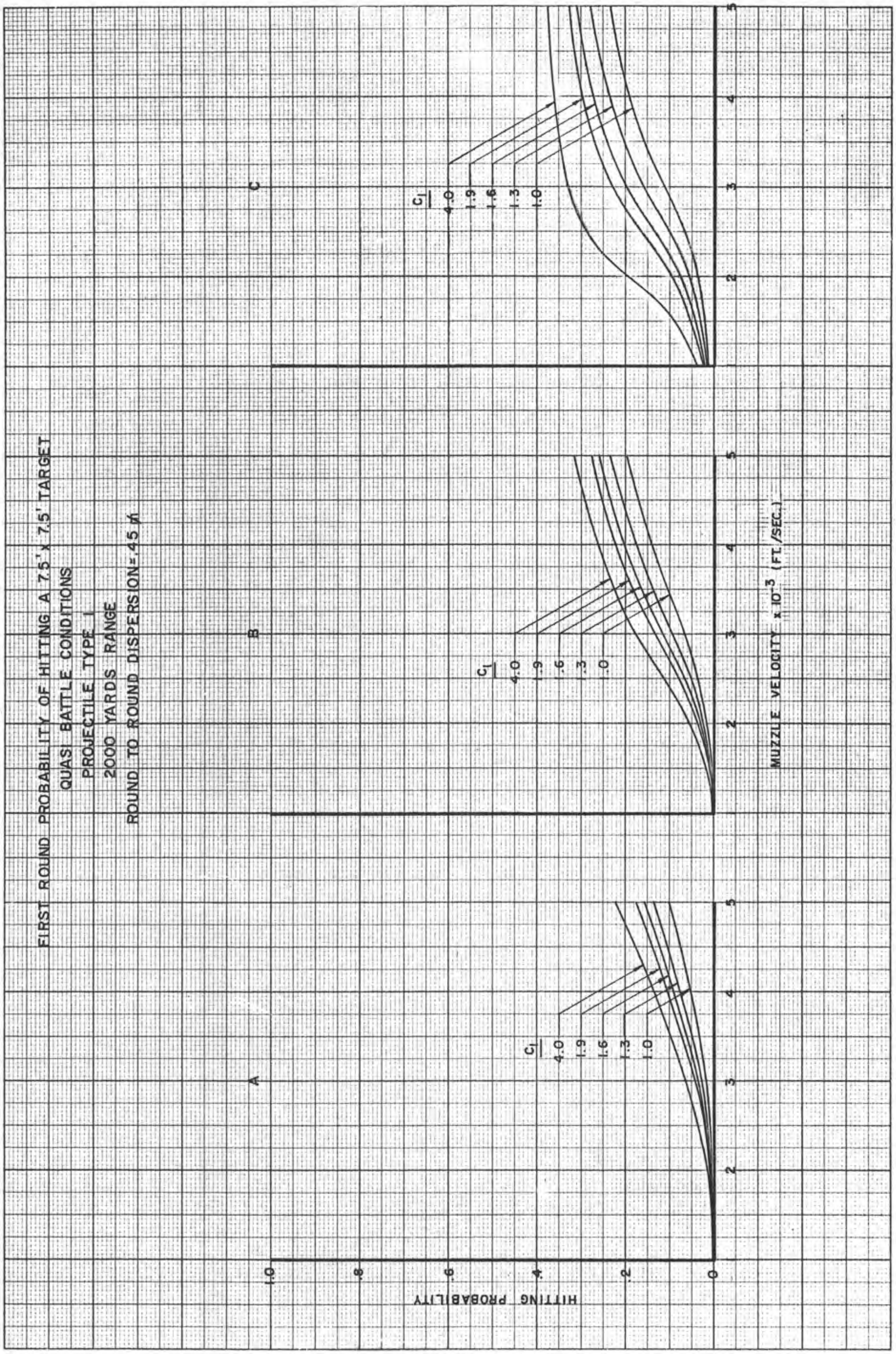
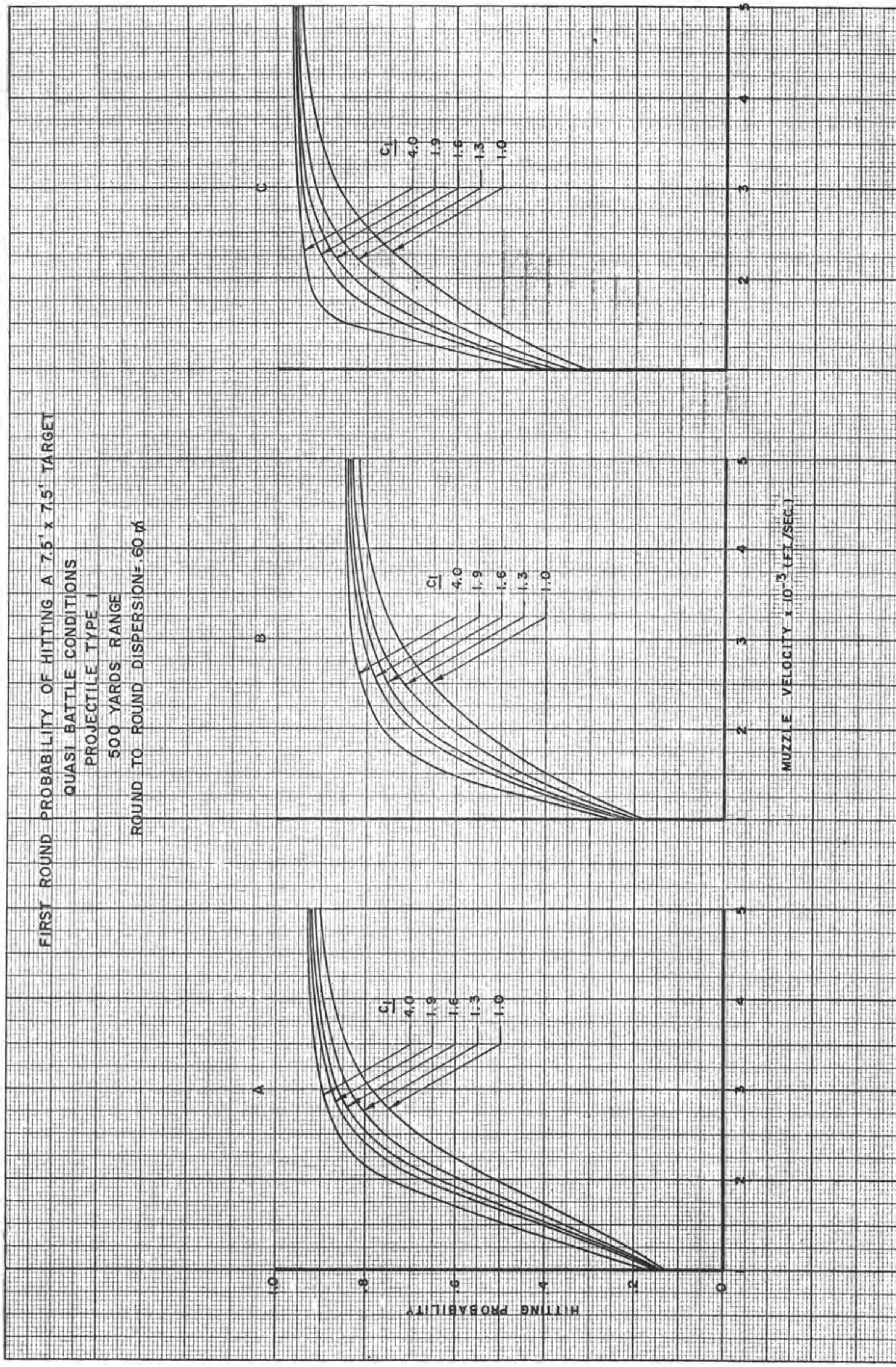
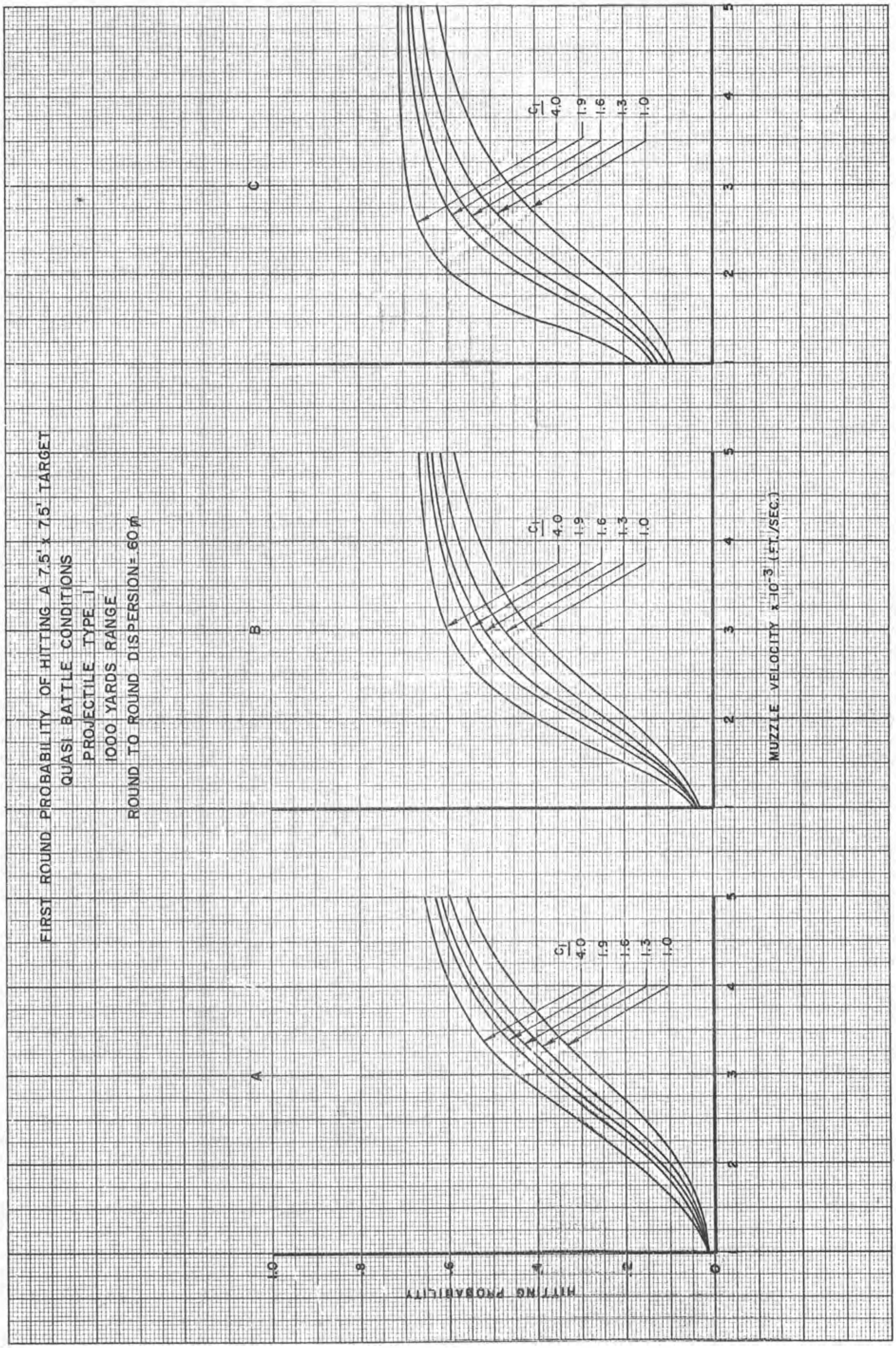
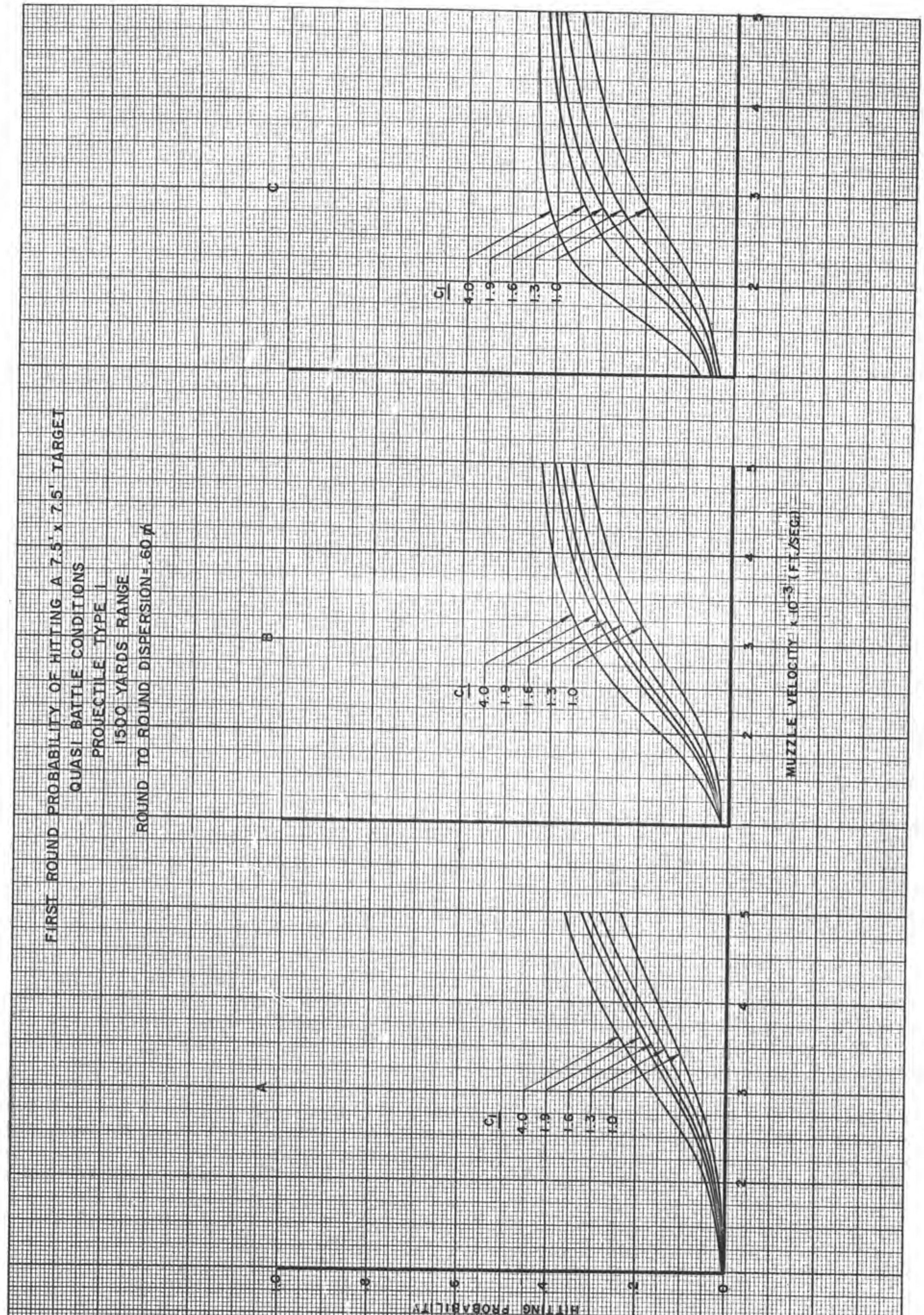
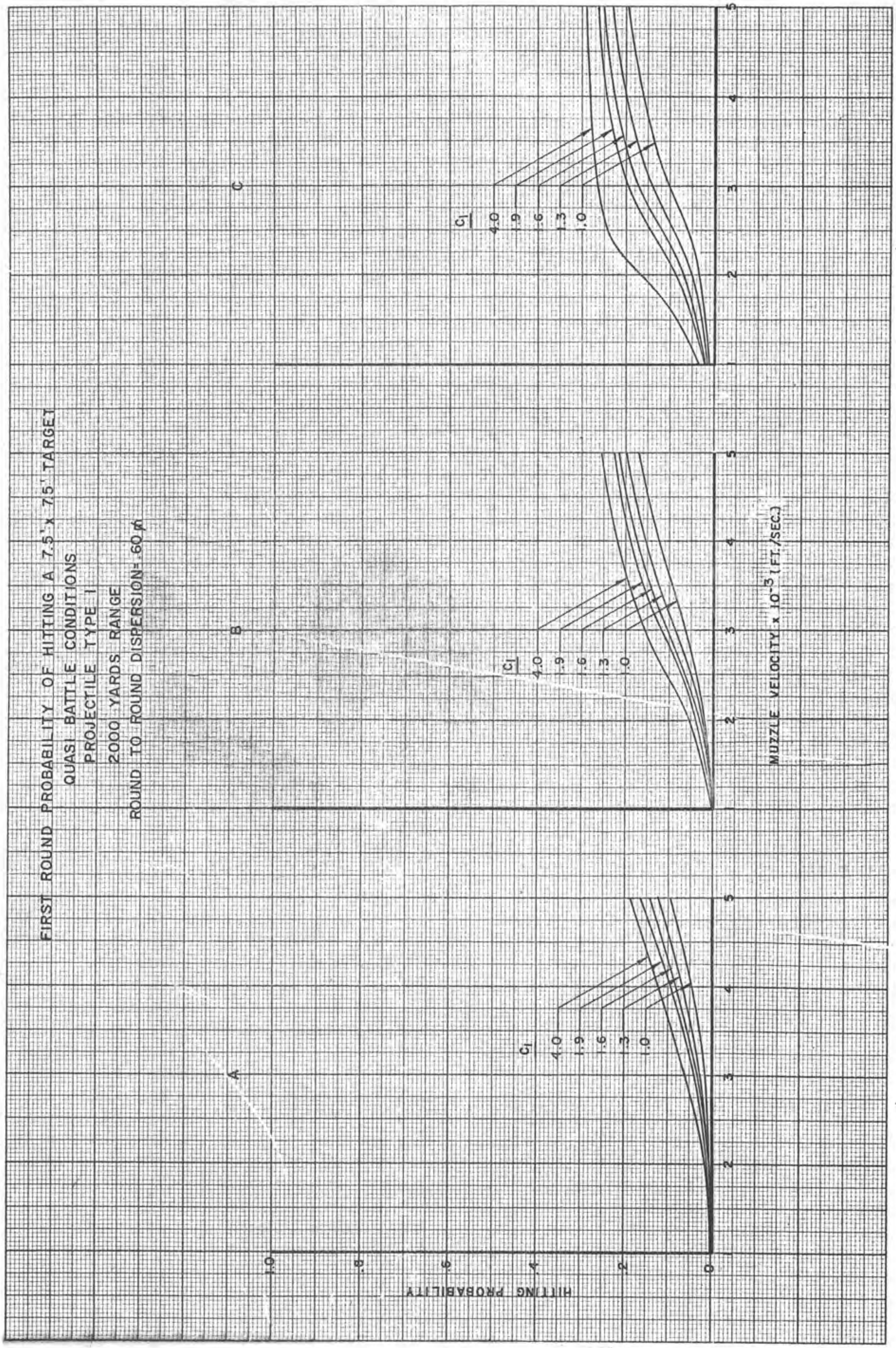

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1500 YARDS RANGE
ROUND TO ROUND DISPERSION = 45 μ
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
2000 YARDS RANGE
ROUND TO ROUND DISPERSION=.45 mil
A
B
C
C_L
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

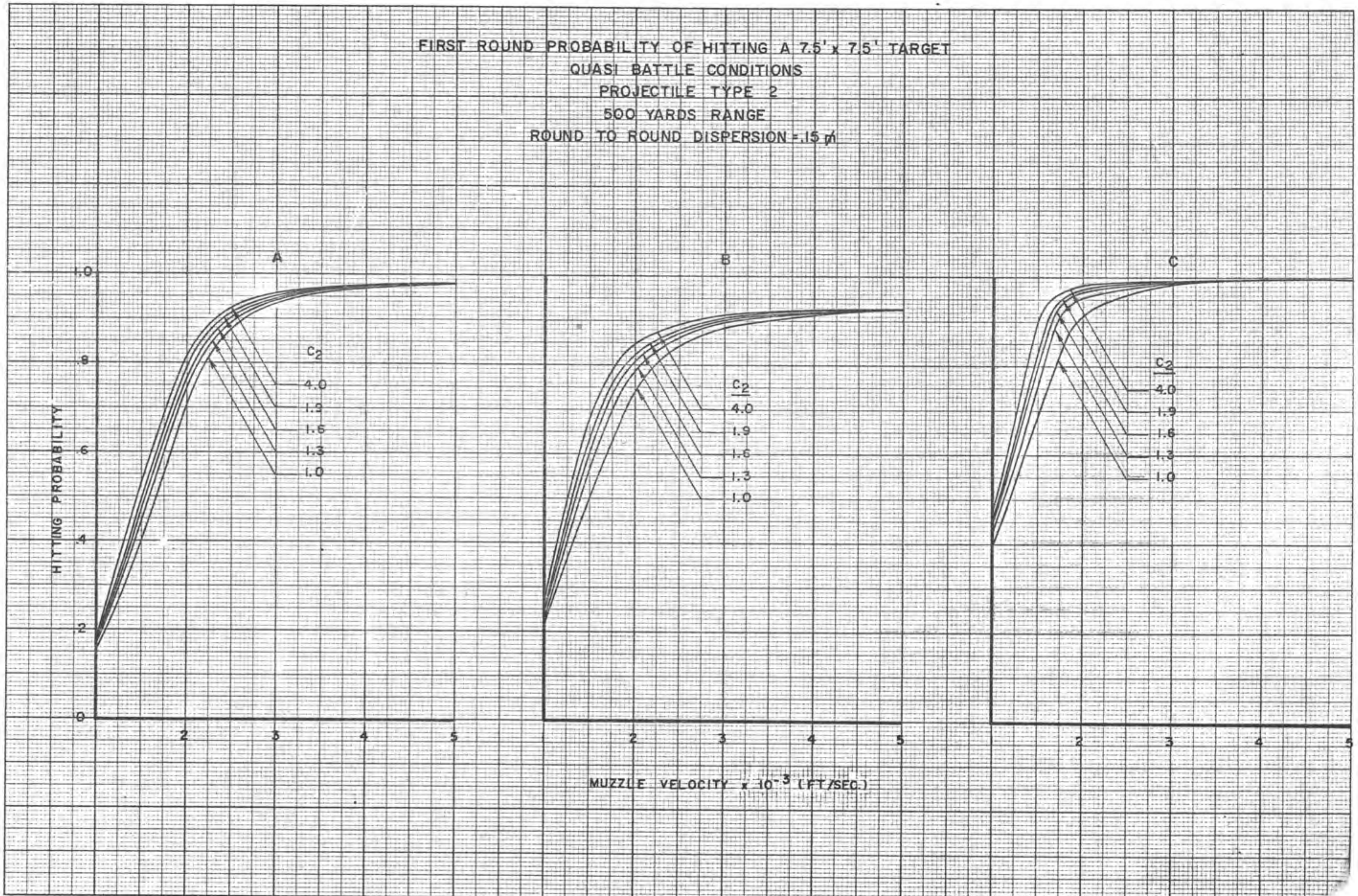

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
500 YARDS RANGE
ROUND TO ROUND DISPERSION= .60 ⌀
A
B
C
C_l
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)
2
3
4
5


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1000 YARDS RANGE
ROUND TO ROUND DISPERSION= 60 µ
A
B
C
C_1
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
MUZZLE VELOCITY x 10⁻³ (FT./SEC.)
0
.2
.4
.6
.8
1.0
2
3
4
5

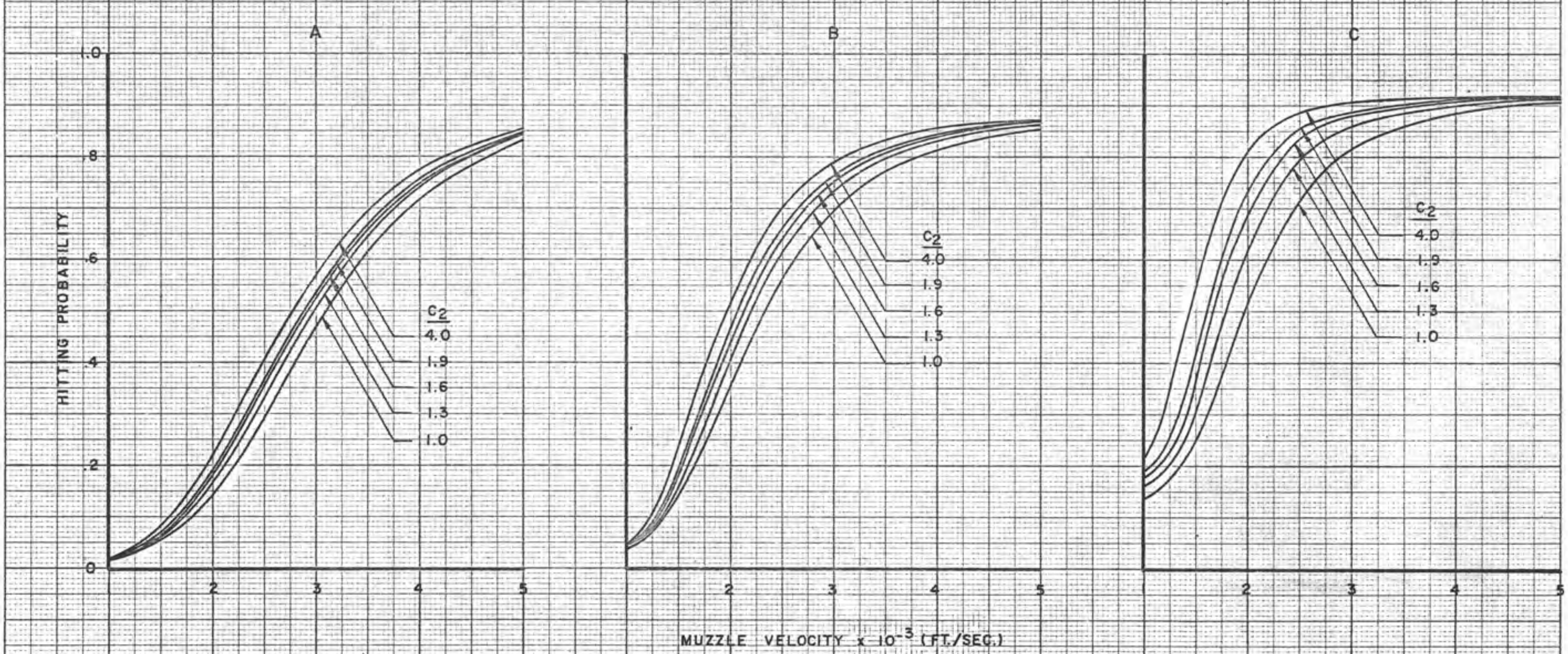

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.60 ₥
A
B
C
C_l
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

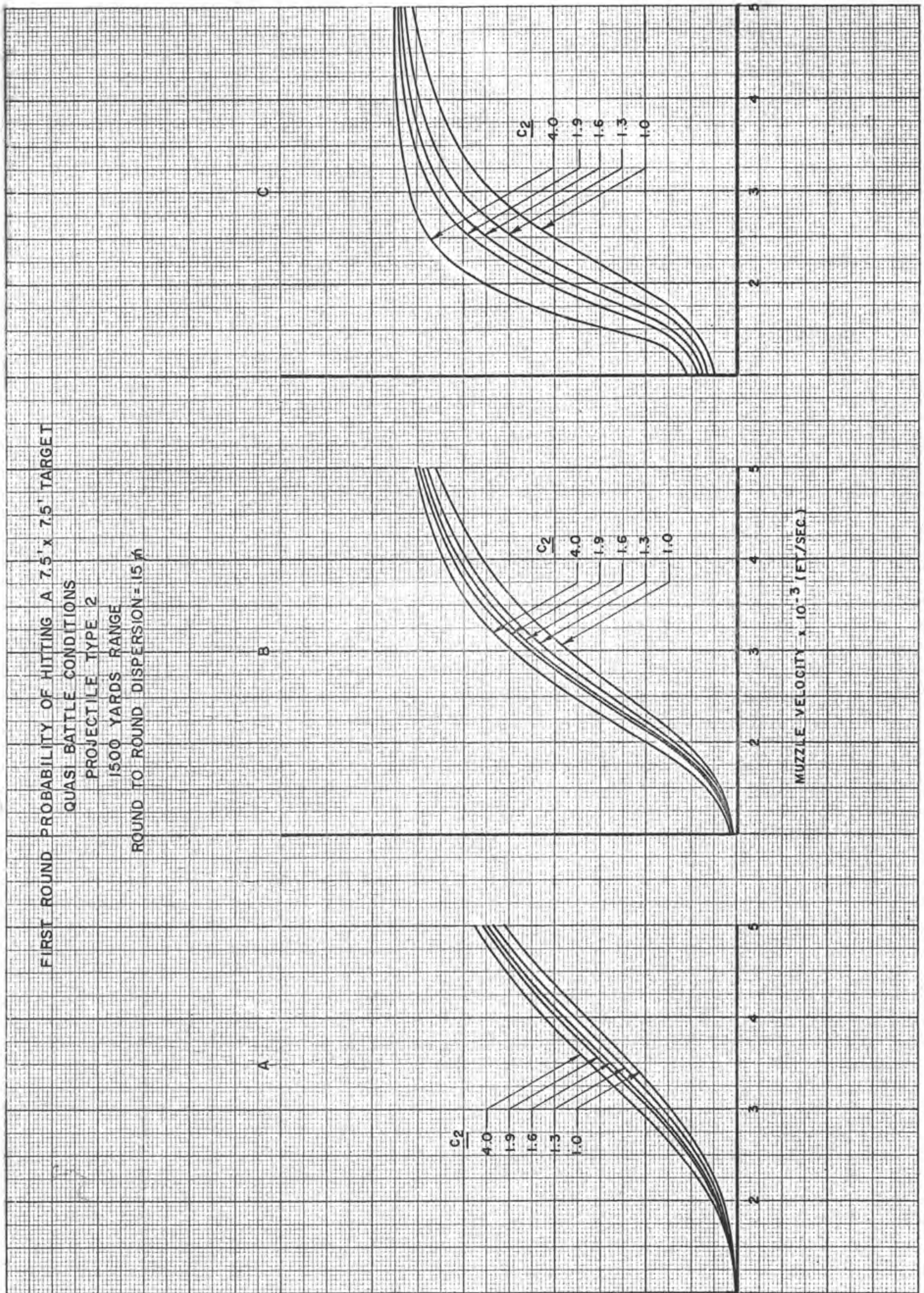

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE I
2000 YARDS RANGE
ROUND TO ROUND DISPERSION=.60
A
B
C
C_1
4.0
.9
.6
.3
.0
1.0
HITTING PROBABILITY
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

Projectile Type 2

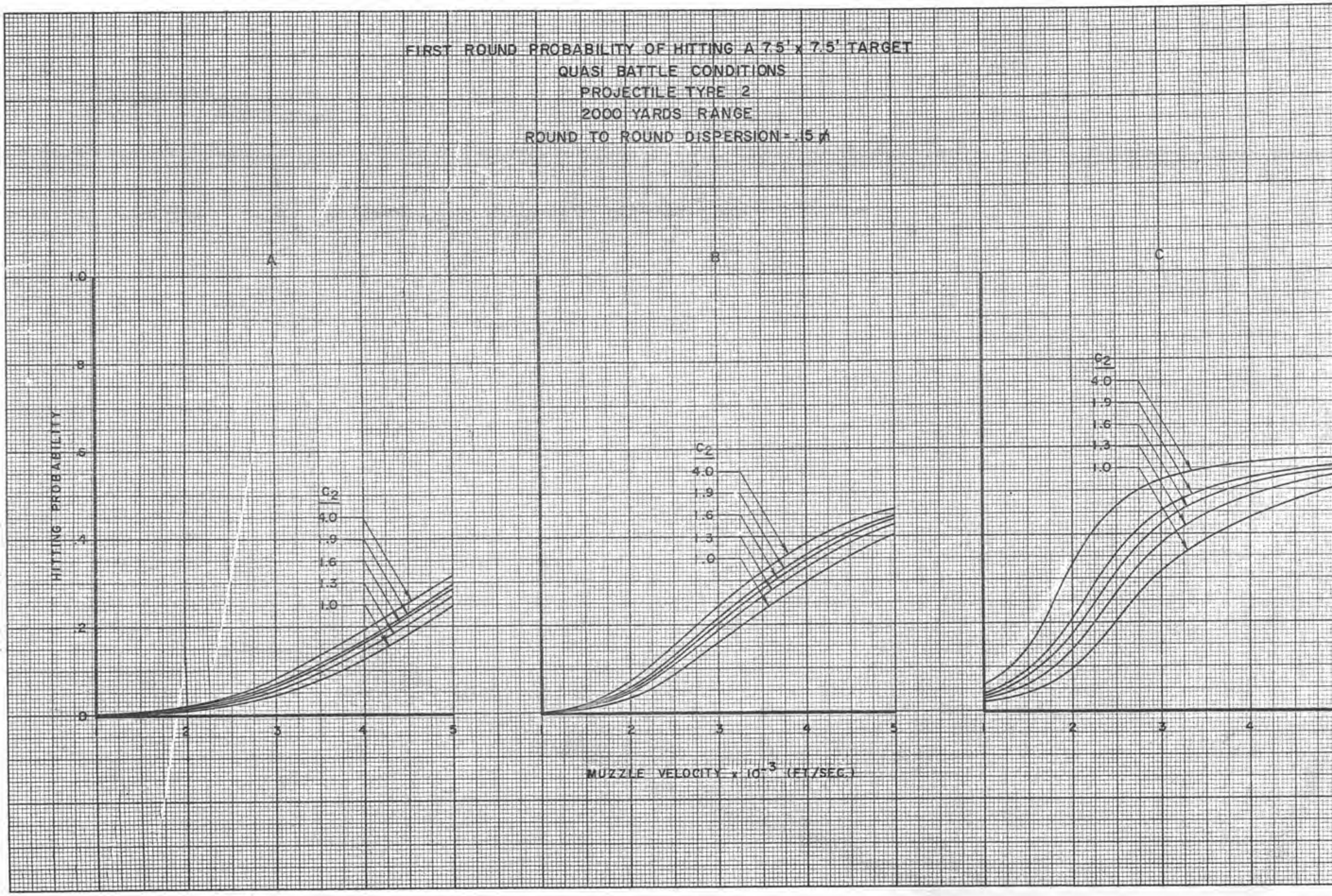

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 mil
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 mil




FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1500 YARDS RANGE
ROUND TO ROUND DISPERSION = 1.5 m
A
B
C
C2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^-3 (FT/SEC.)

[redacted]



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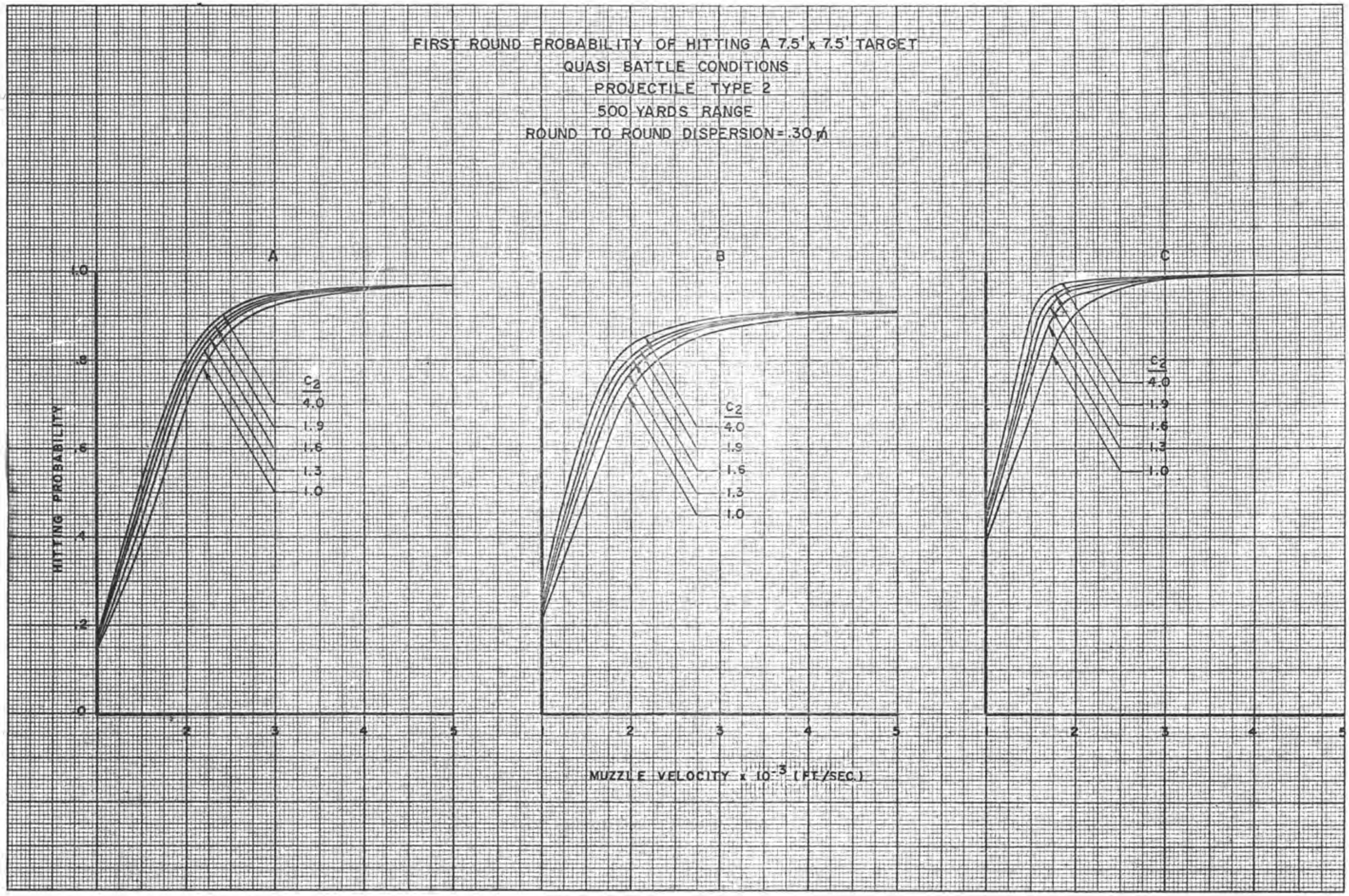
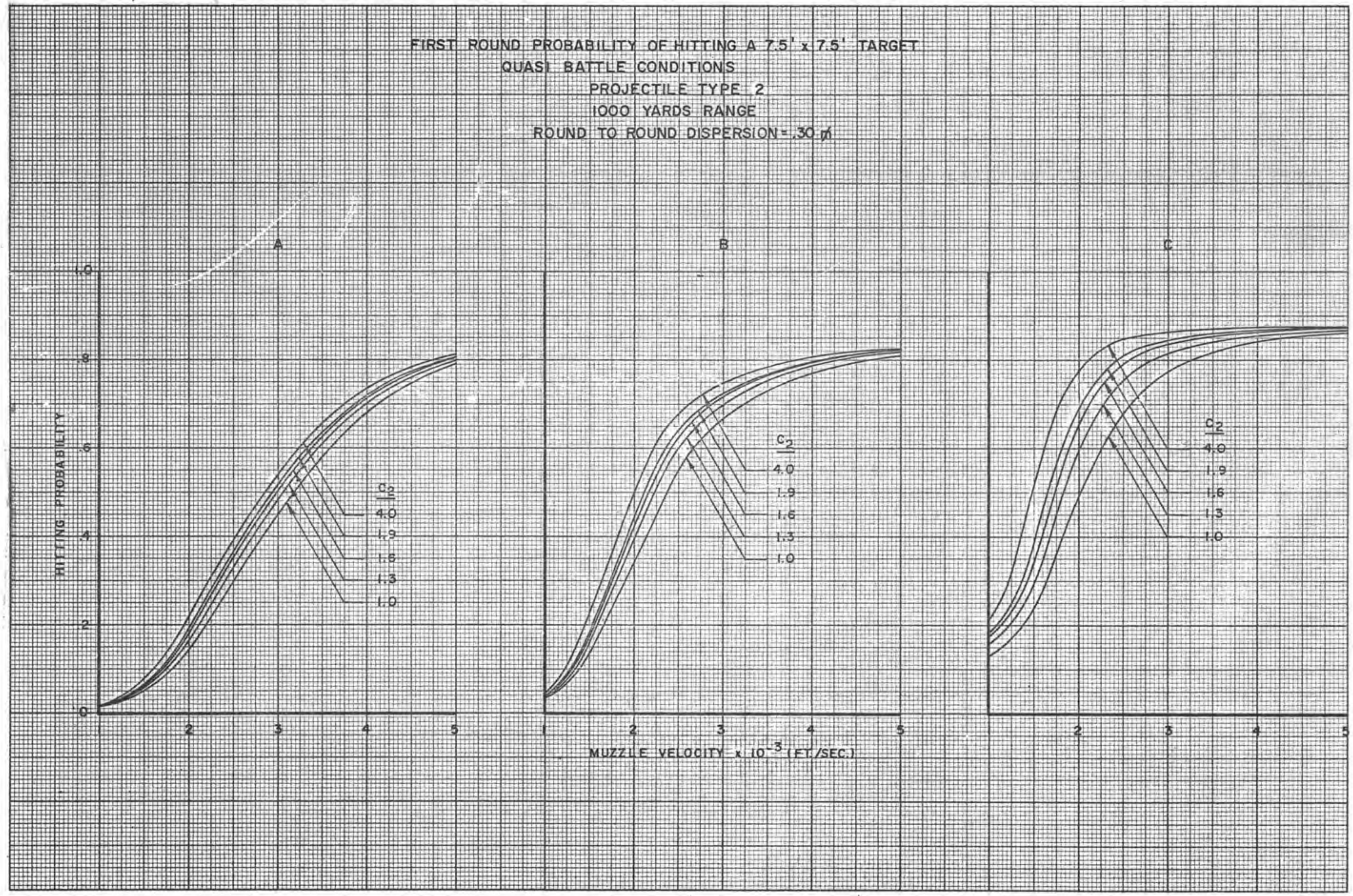
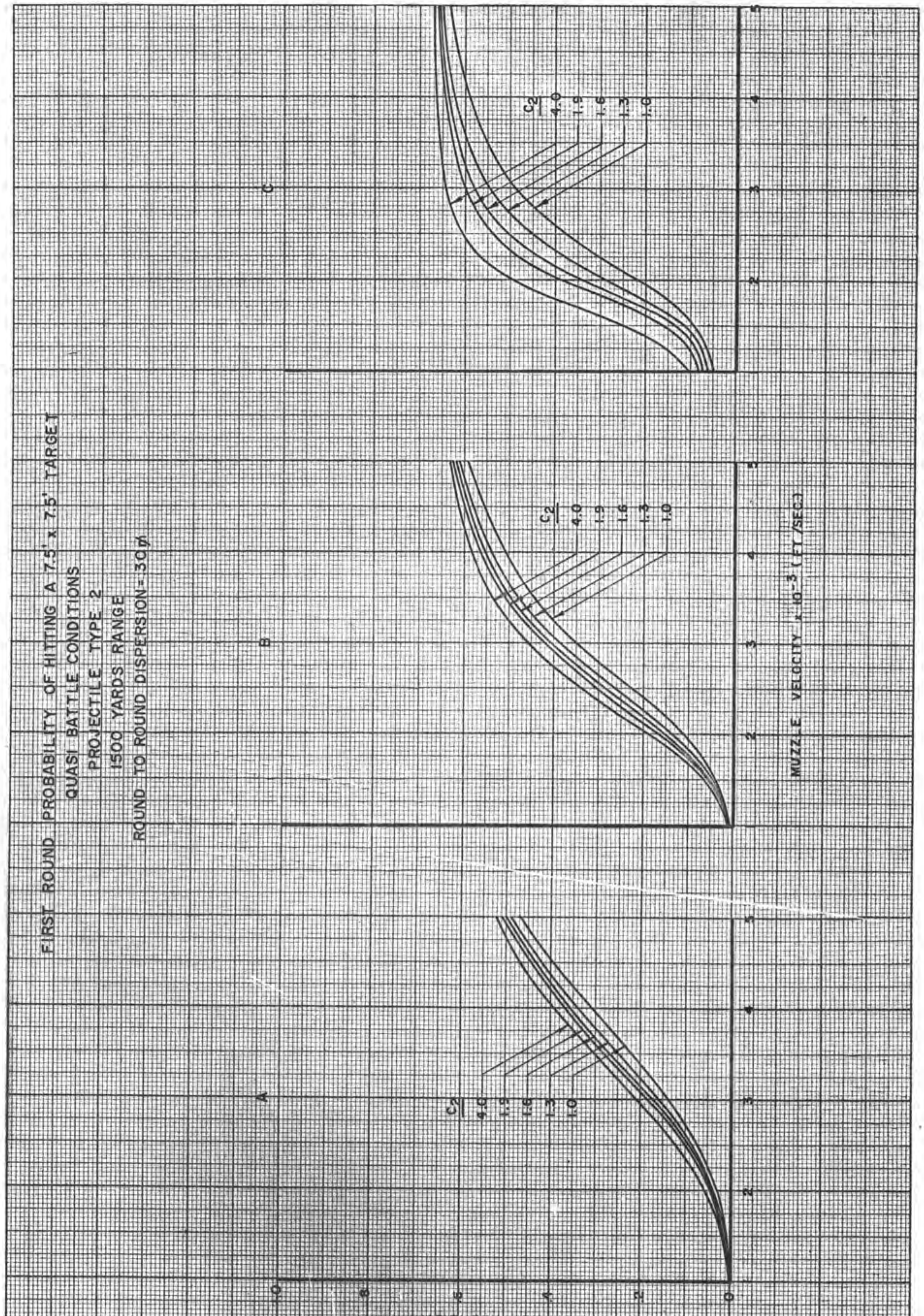
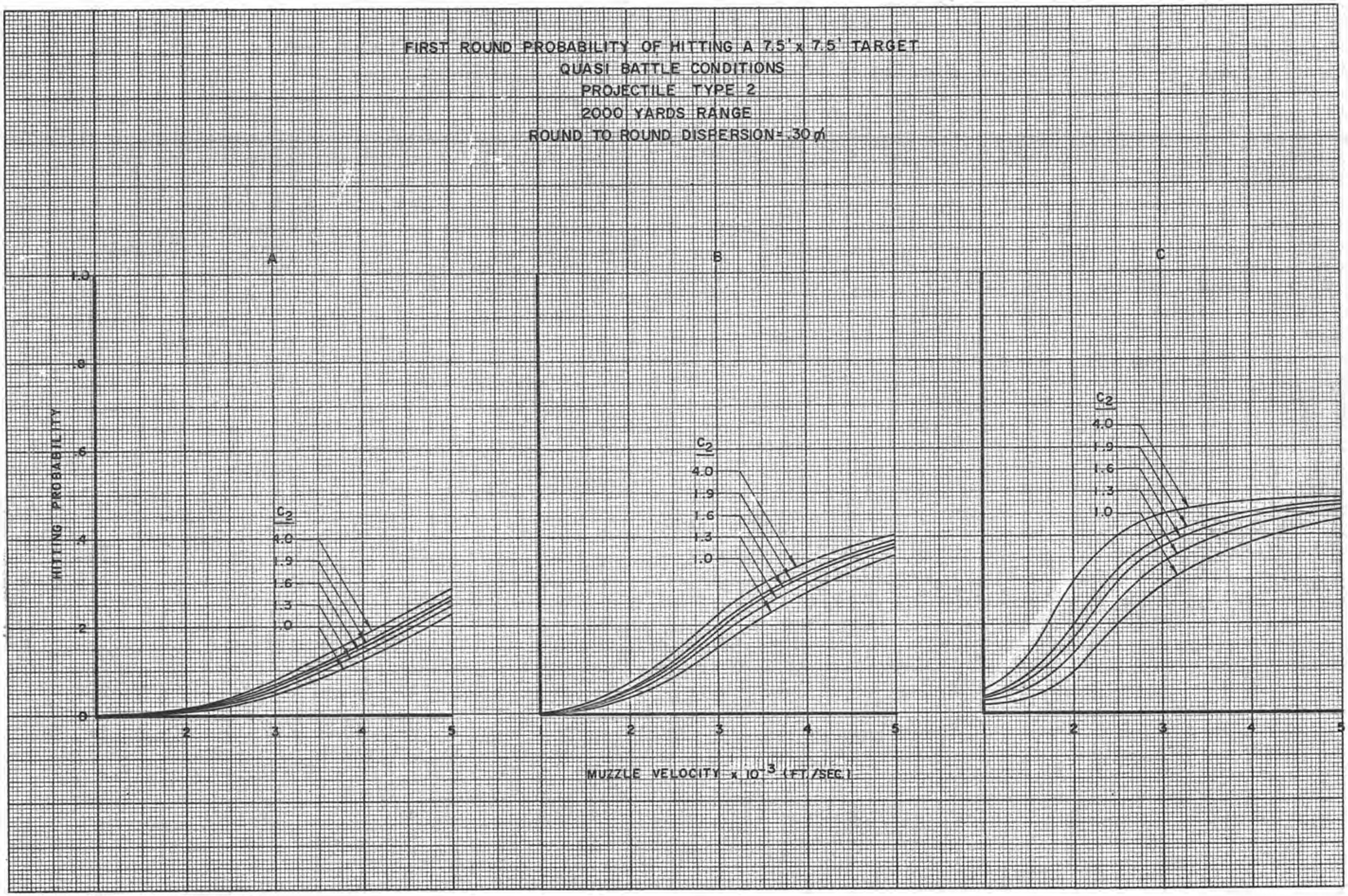
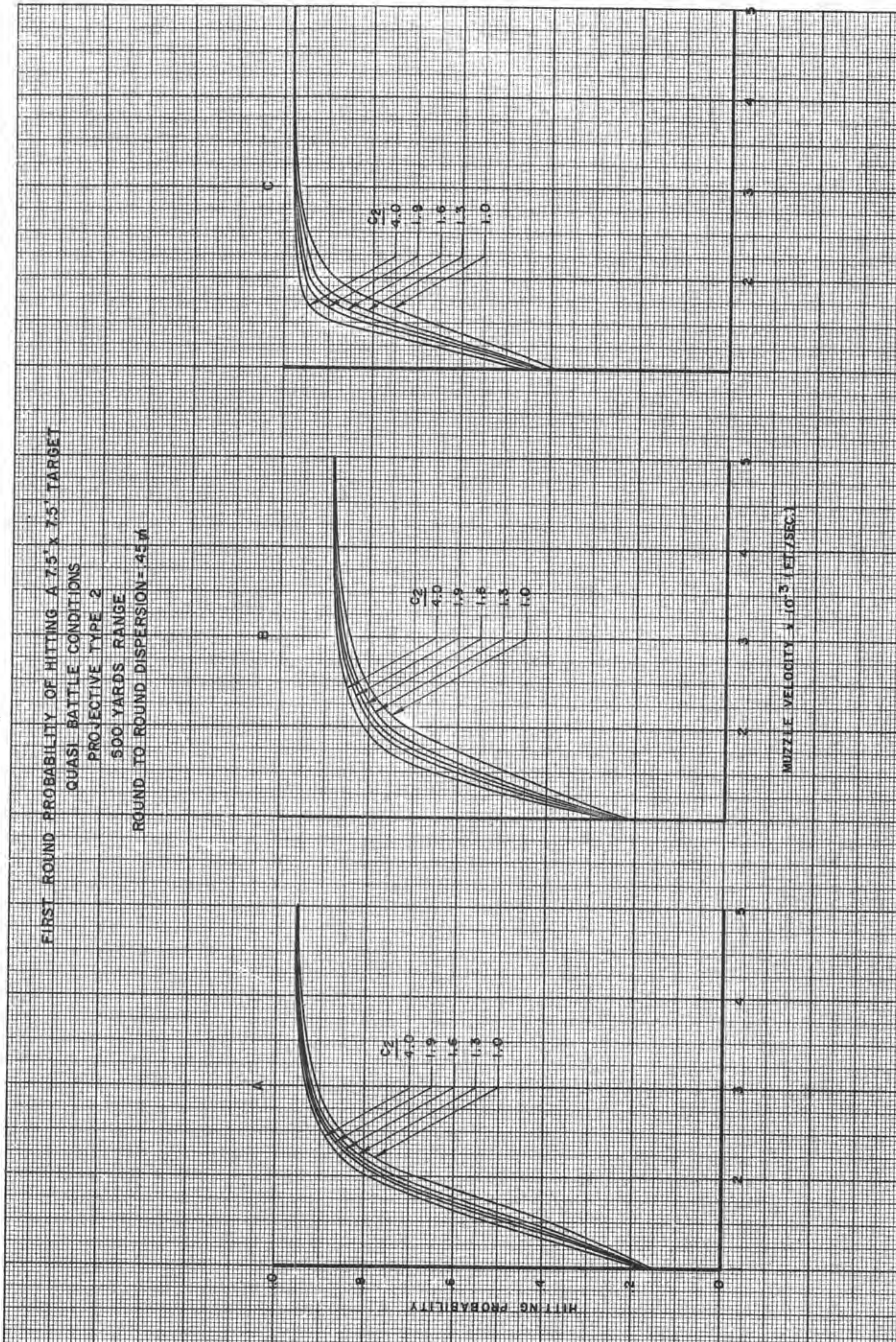
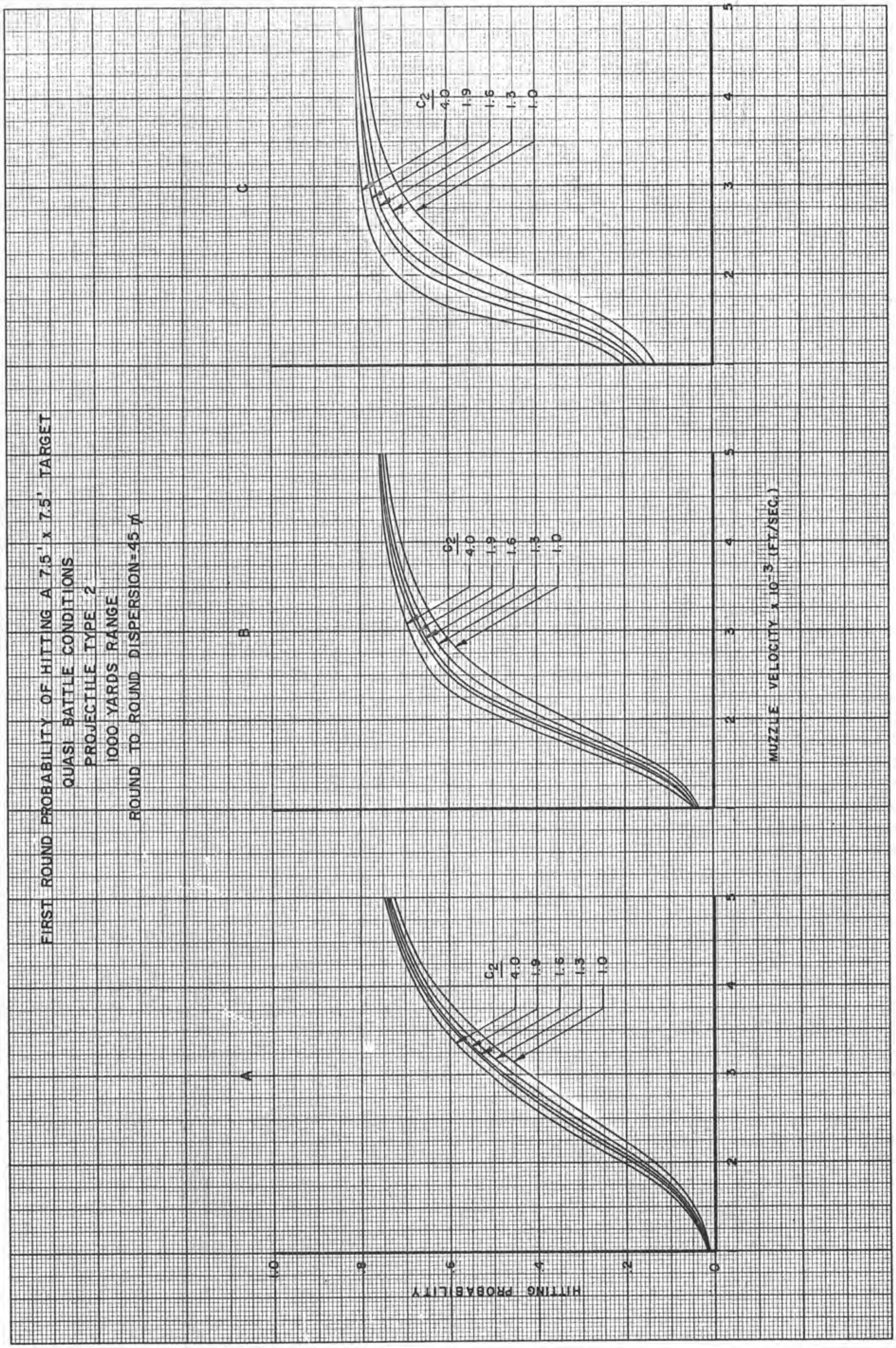

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C_2
4.0
1.9
1.6
1.3
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

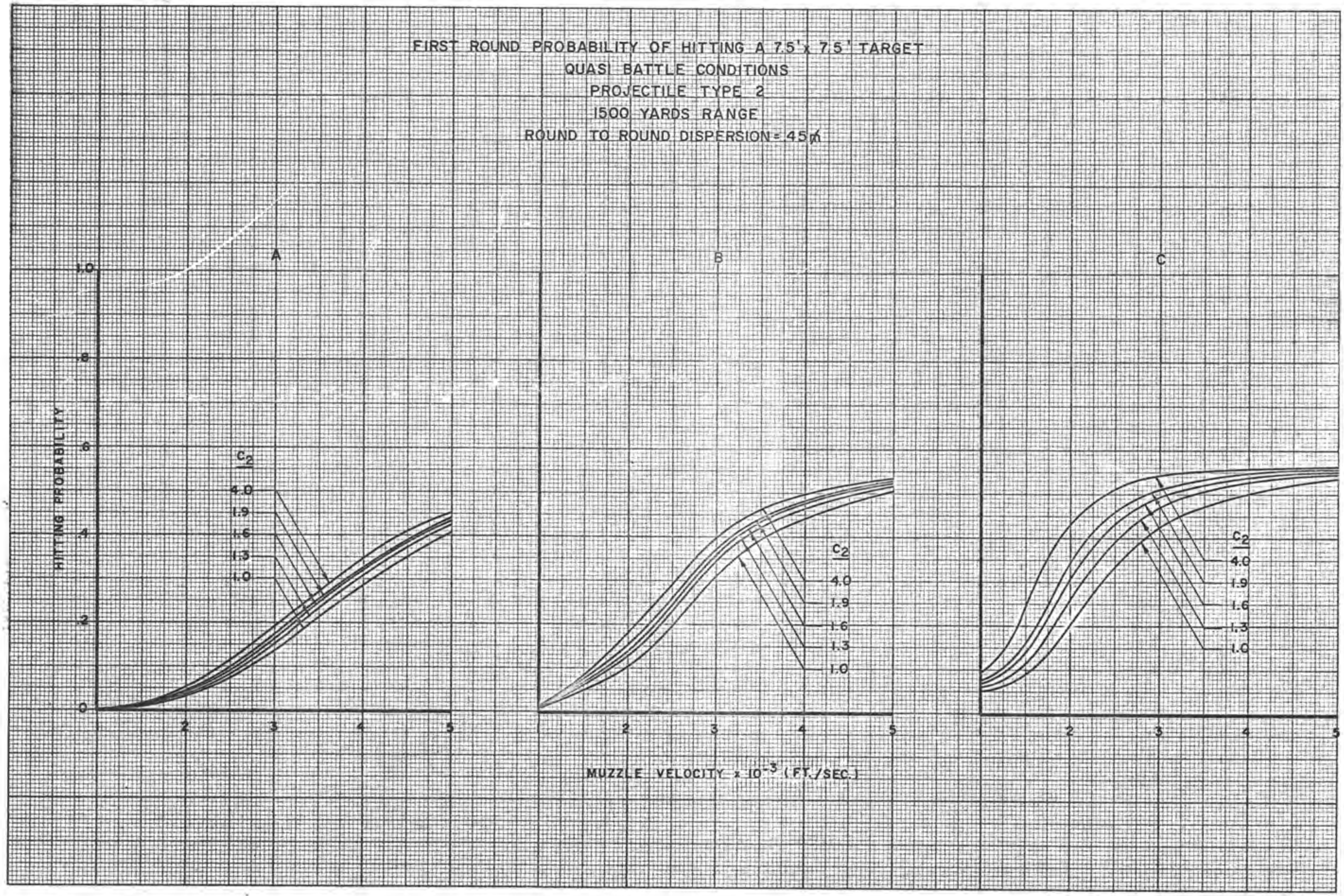

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1500 YARDS RANGE
ROUND TO ROUND DISPERSION = 30
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)
0
.2
.4
.6
.8
1.0
2
3
4
5


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 m
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTIVE TYPE 2
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .45 m̸
A
B
C
C2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^3 (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1000 YARDS RANGE
ROUND TO ROUND DISPERSION=.45 mil
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

[redacted]



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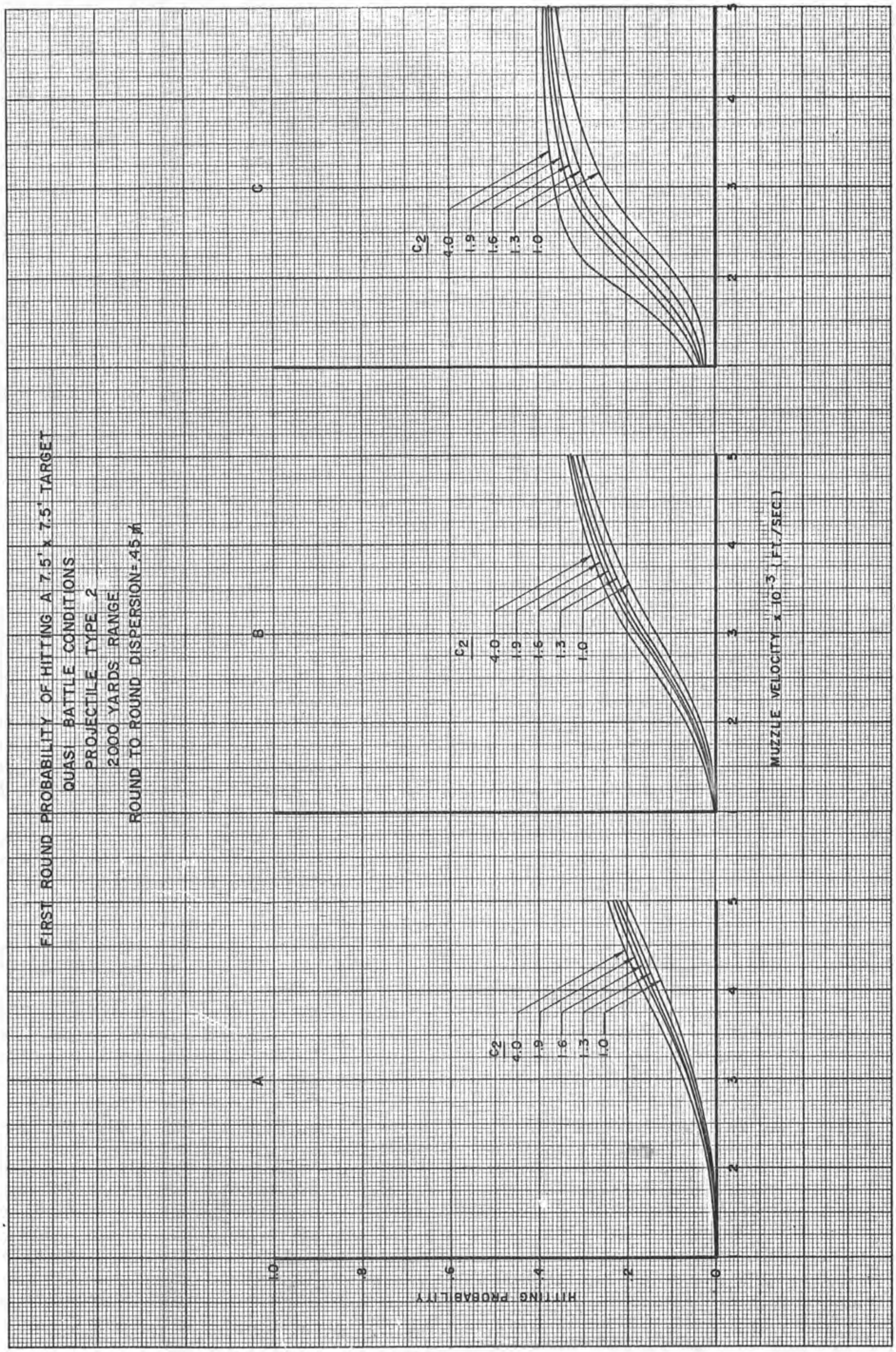

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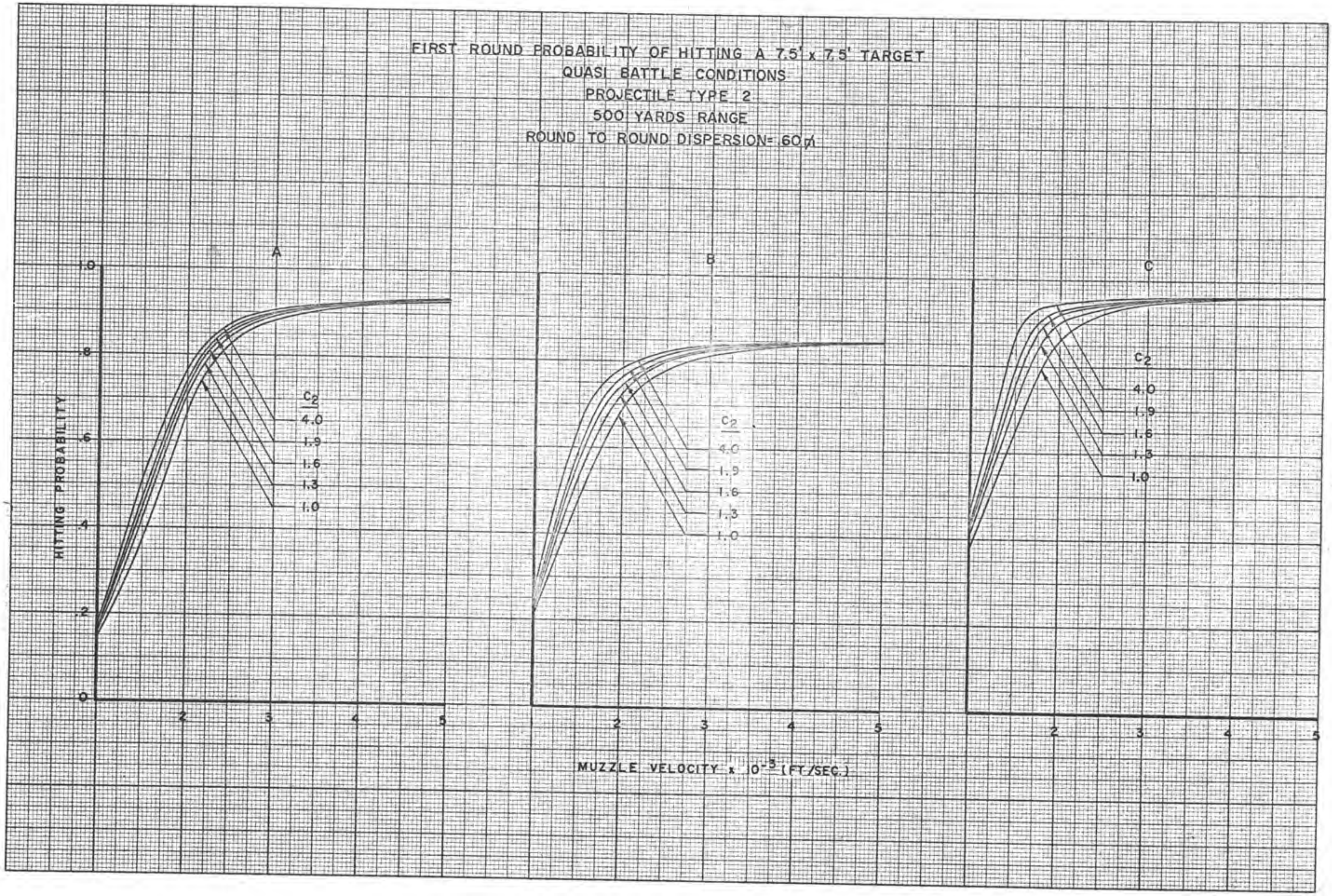
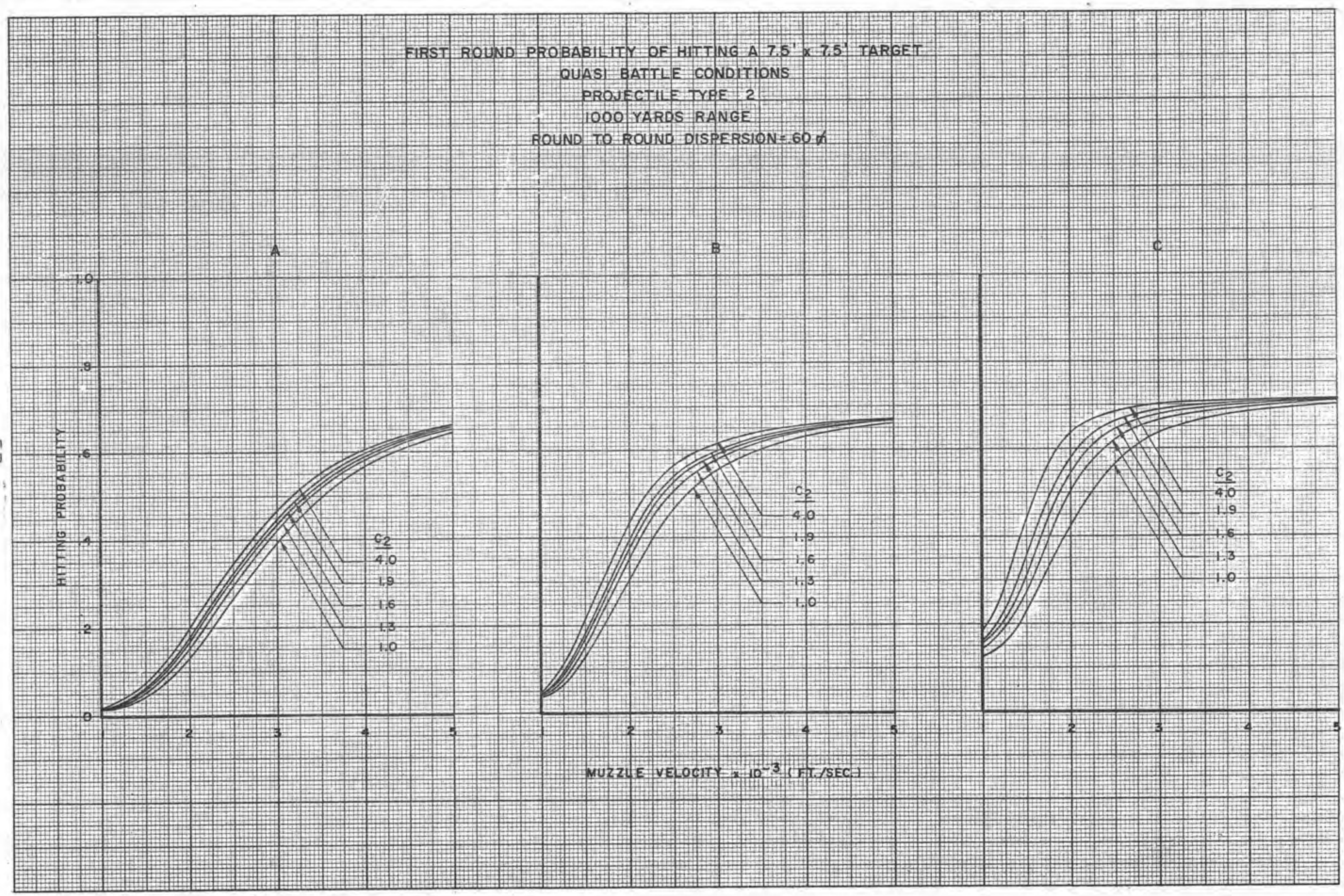
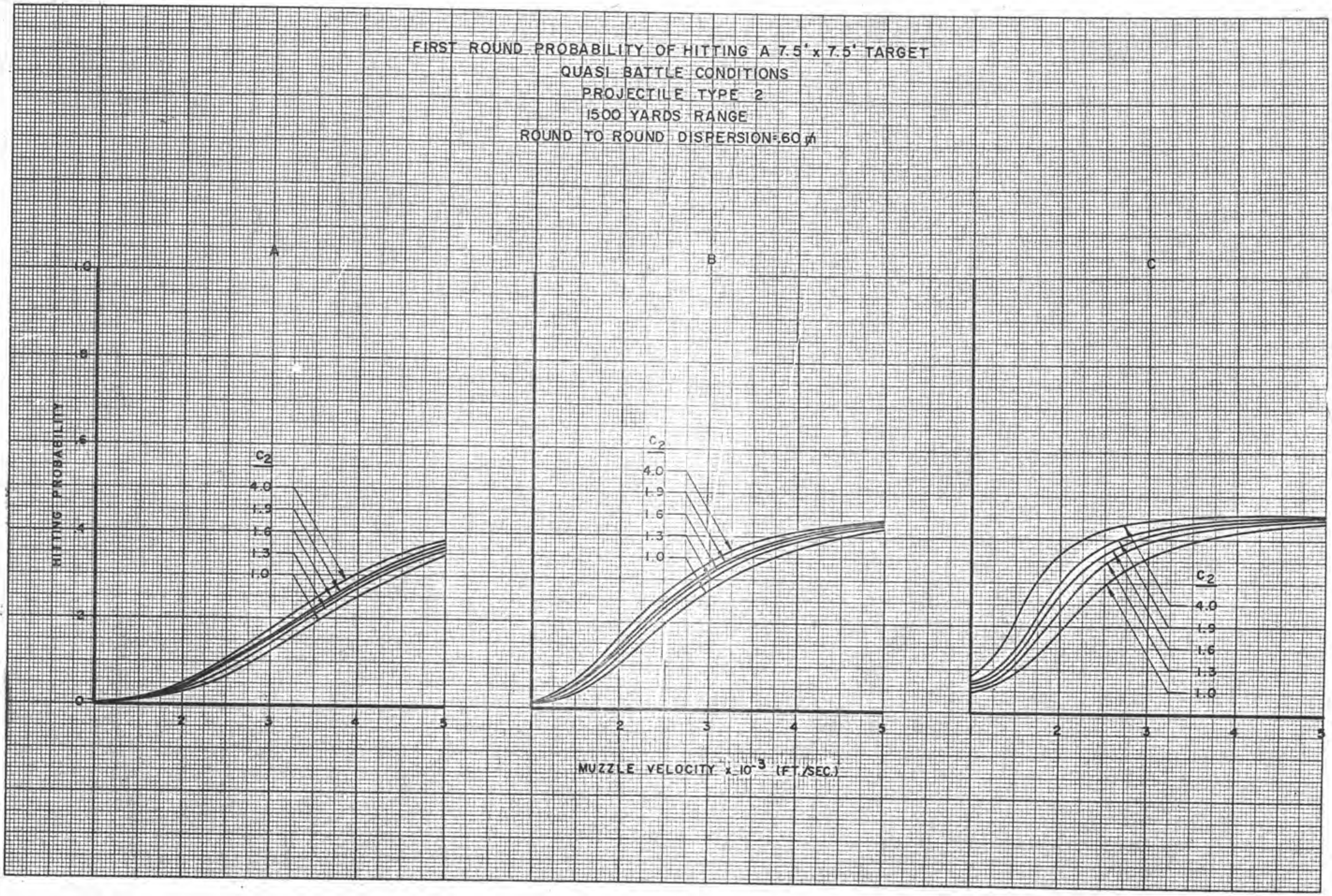
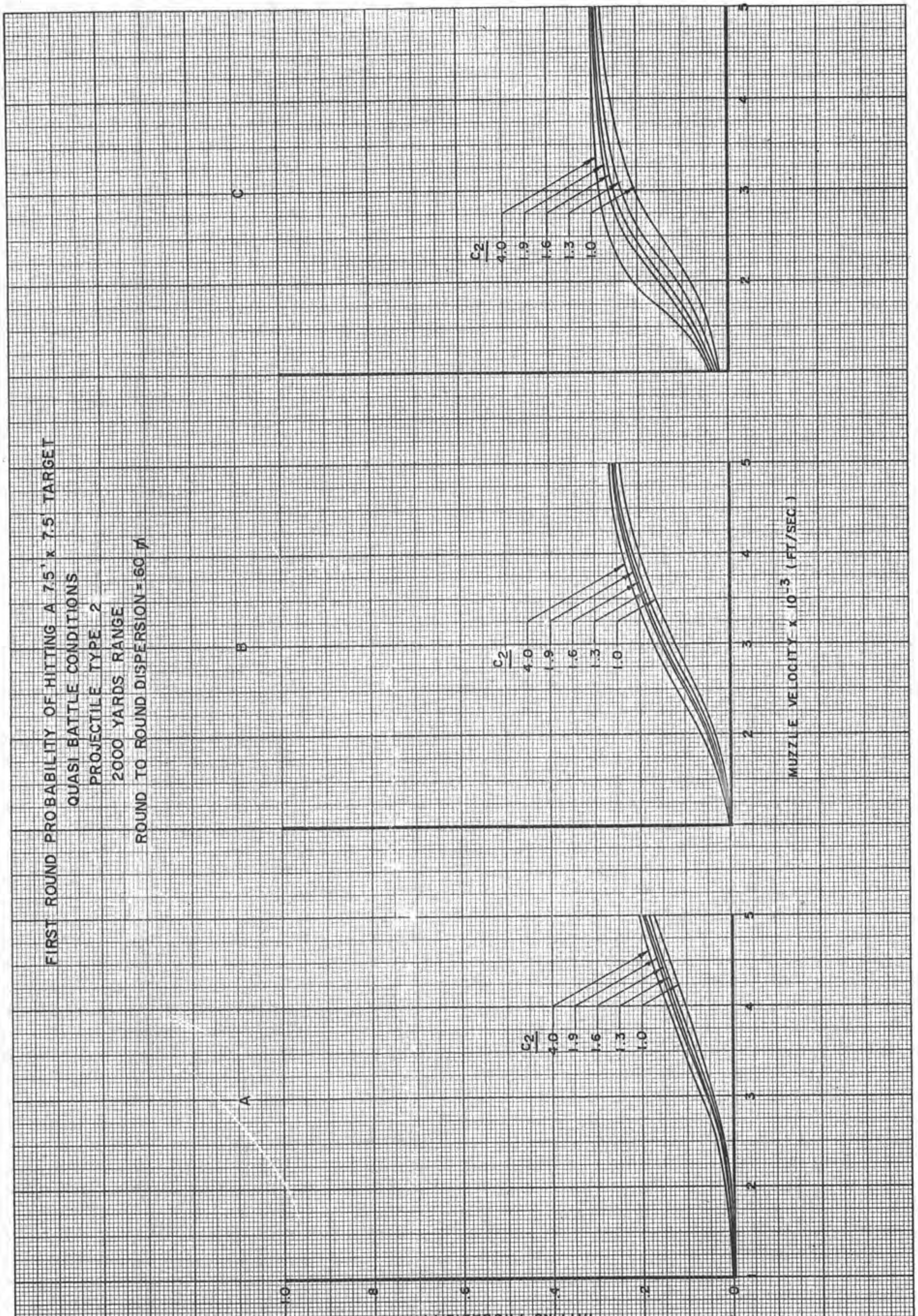
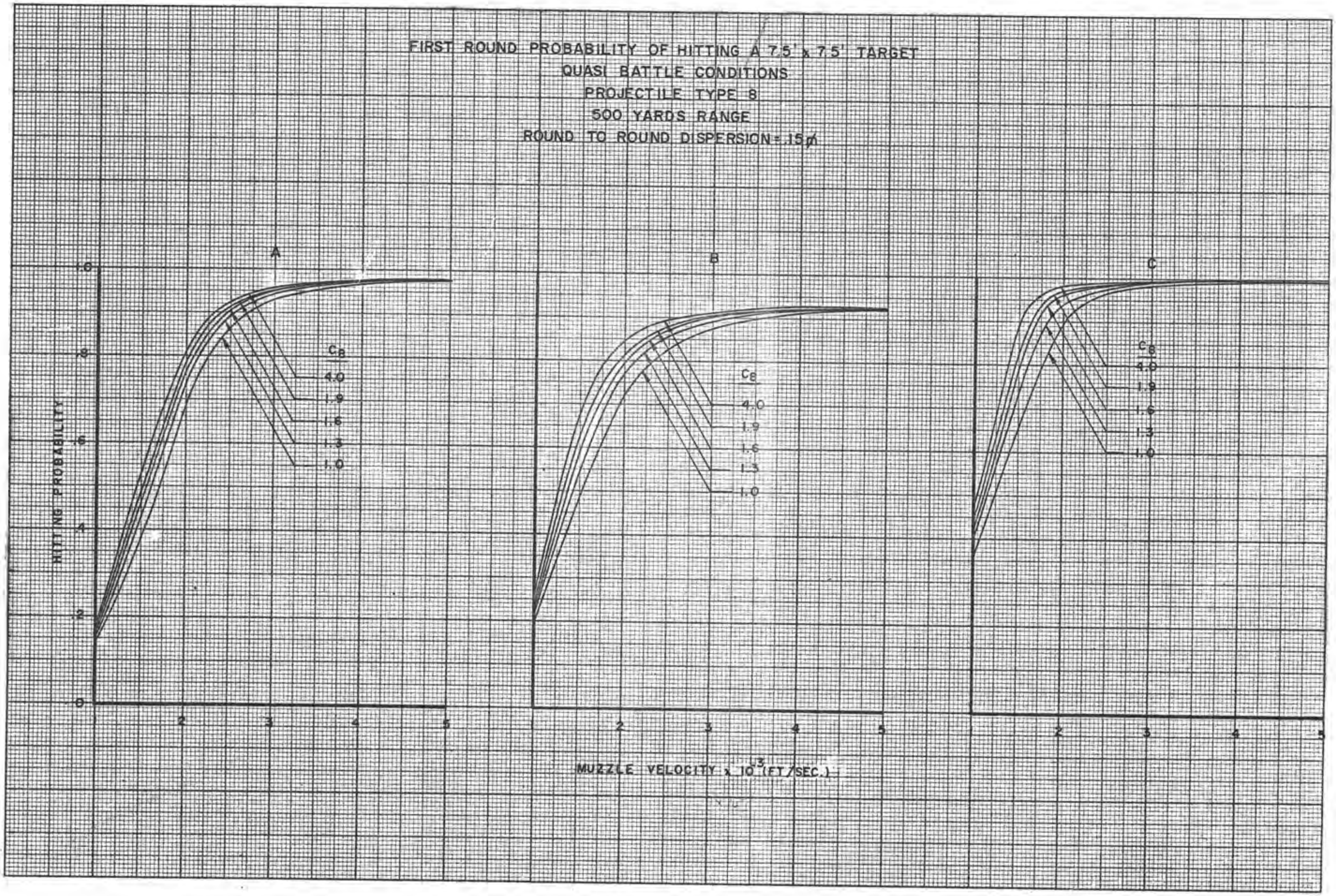

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
500 YARDS RANGE
ROUND TO ROUND DISPERSION= 60 μ
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C2
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^-3 (FT./SEC.)

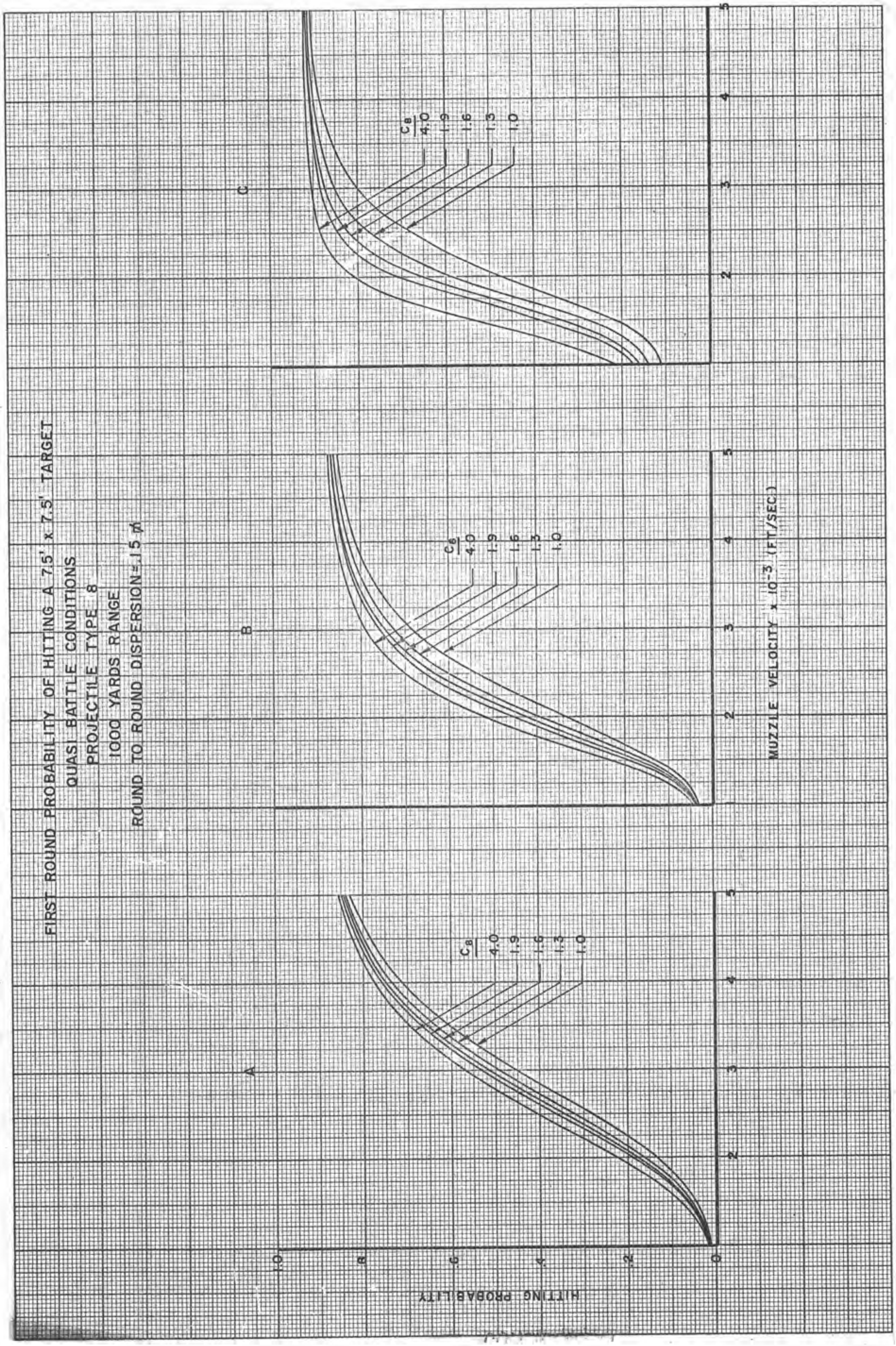

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .60 ₥
A
B
C
HITTING PROBABILITY
C_2
4.0
1.9
1.6
1.3
1.0
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=60 μ
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C_2
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

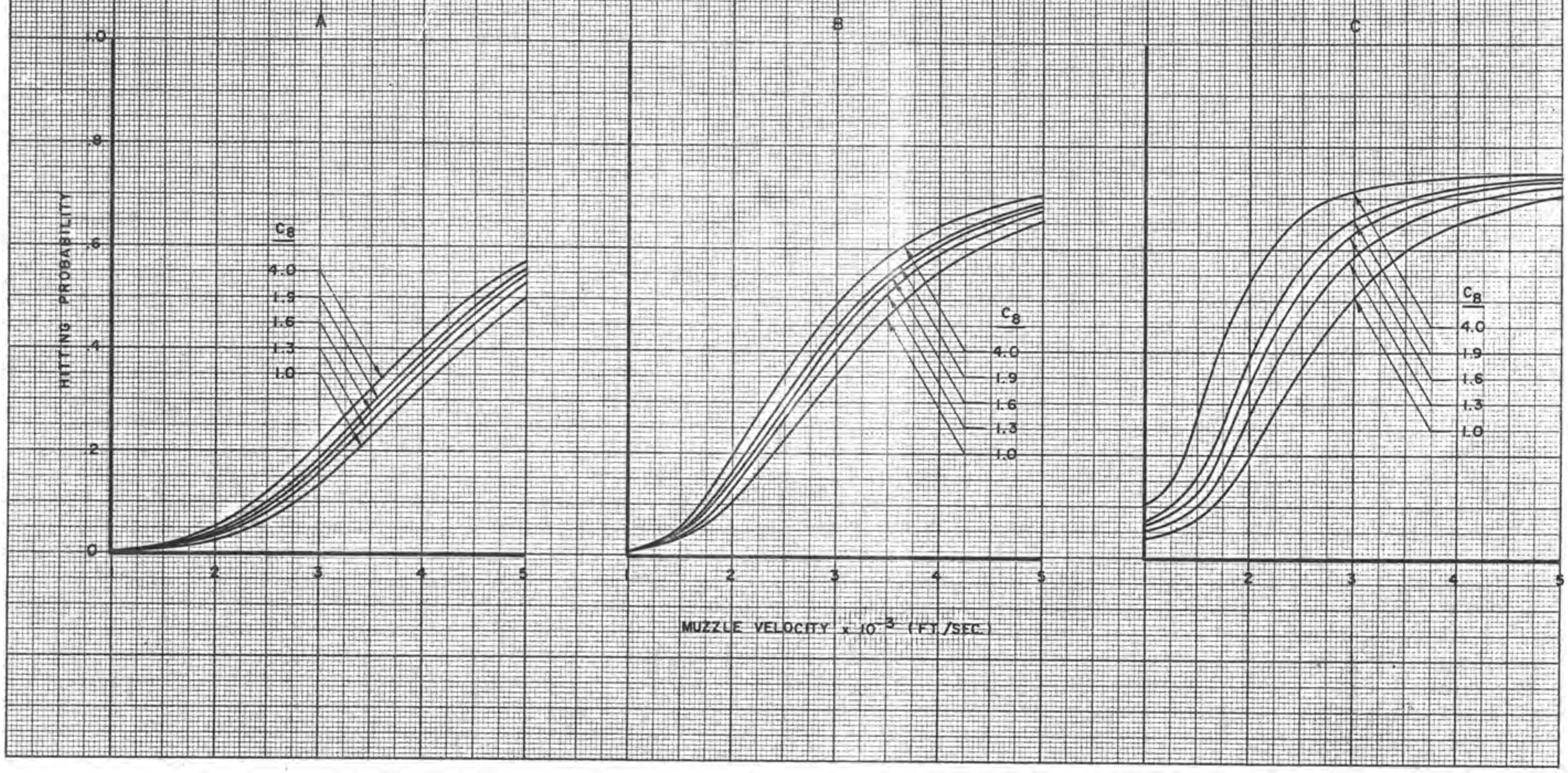

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 2
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = 60 μ
A
B
C
C_2
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)

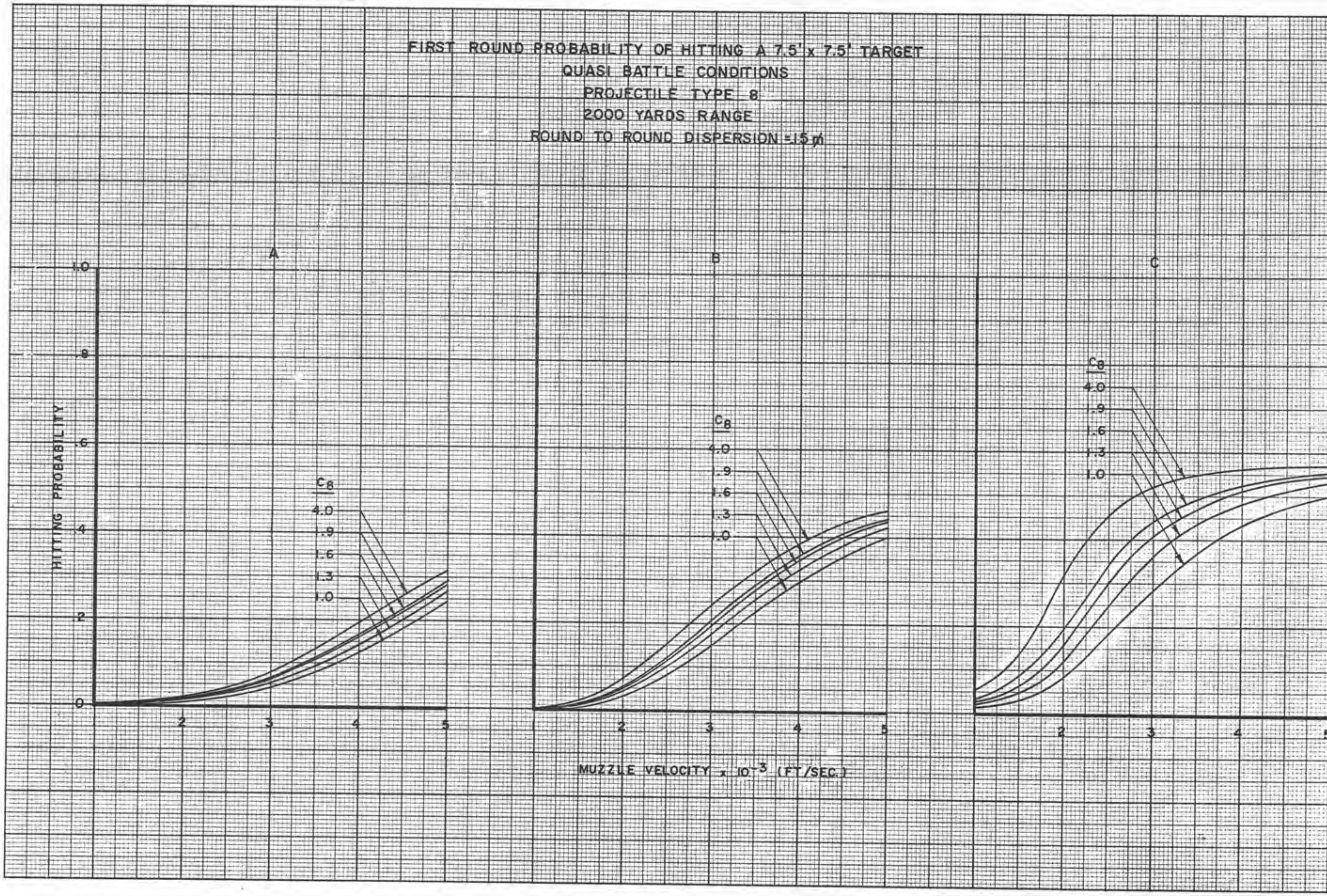
Projectile Type 8


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .15ϕ
A
B
C
C_B
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

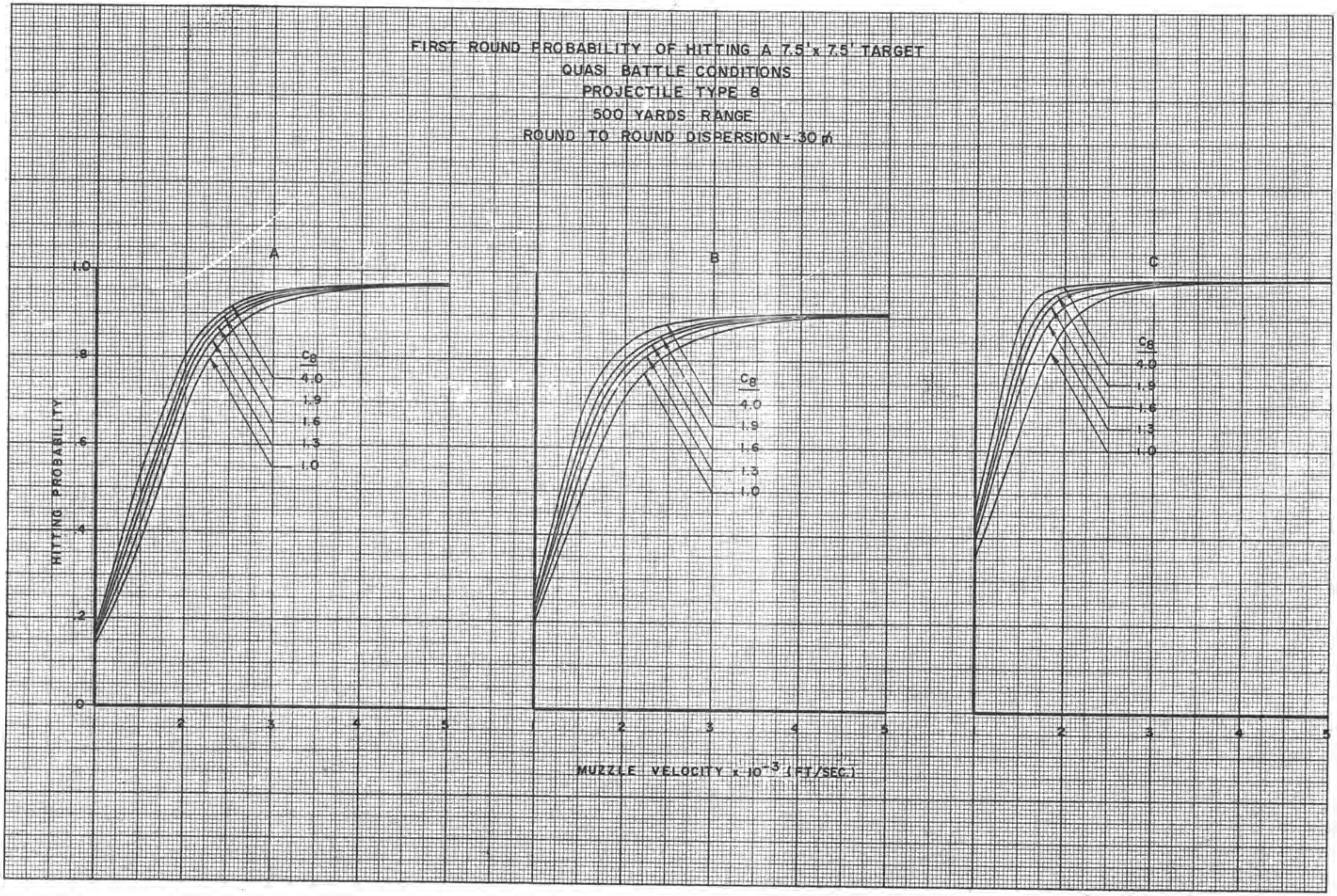

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .15 ⌀
A
B
C
C_δ
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
1
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC)

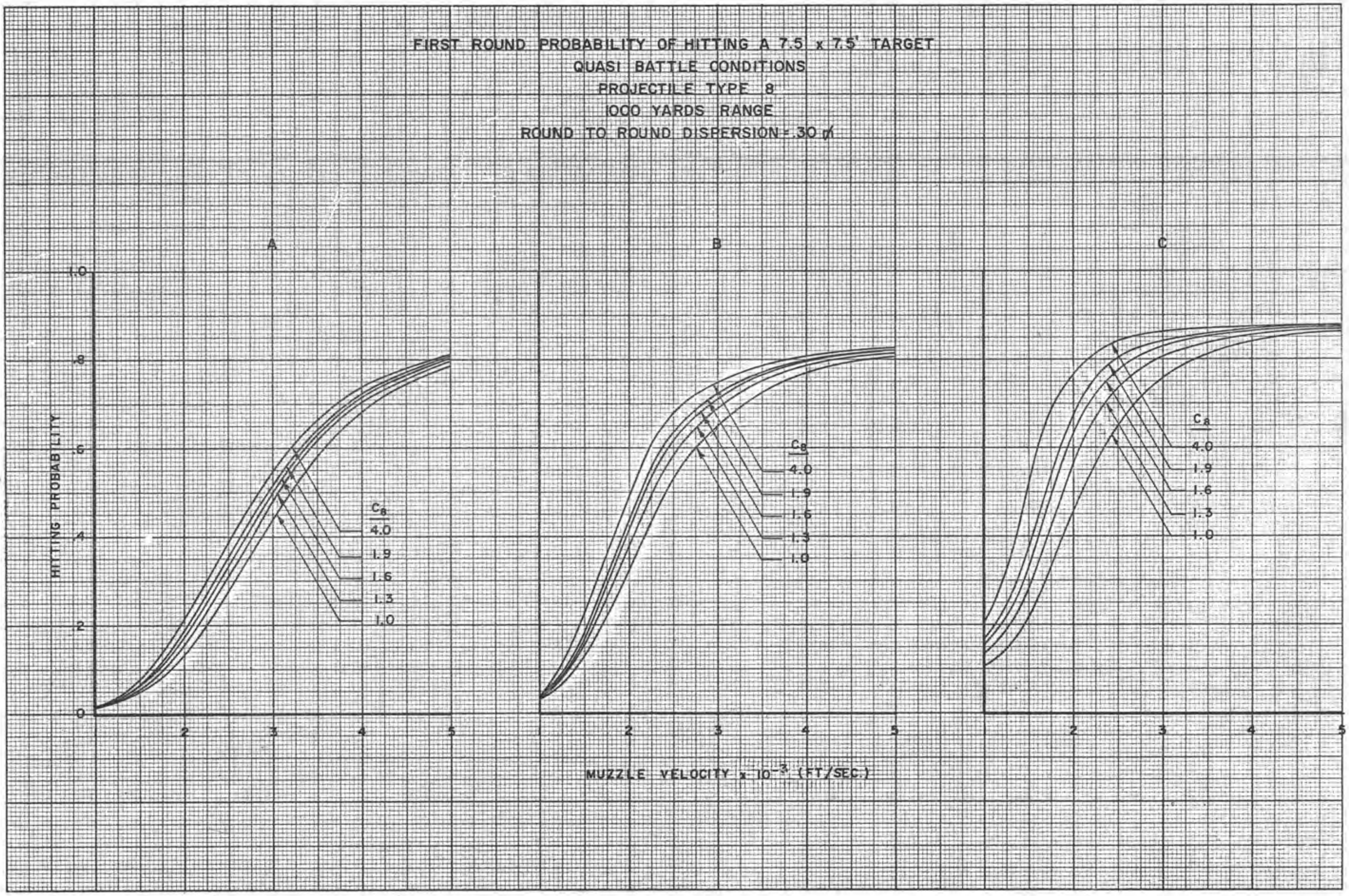
FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.15 mil

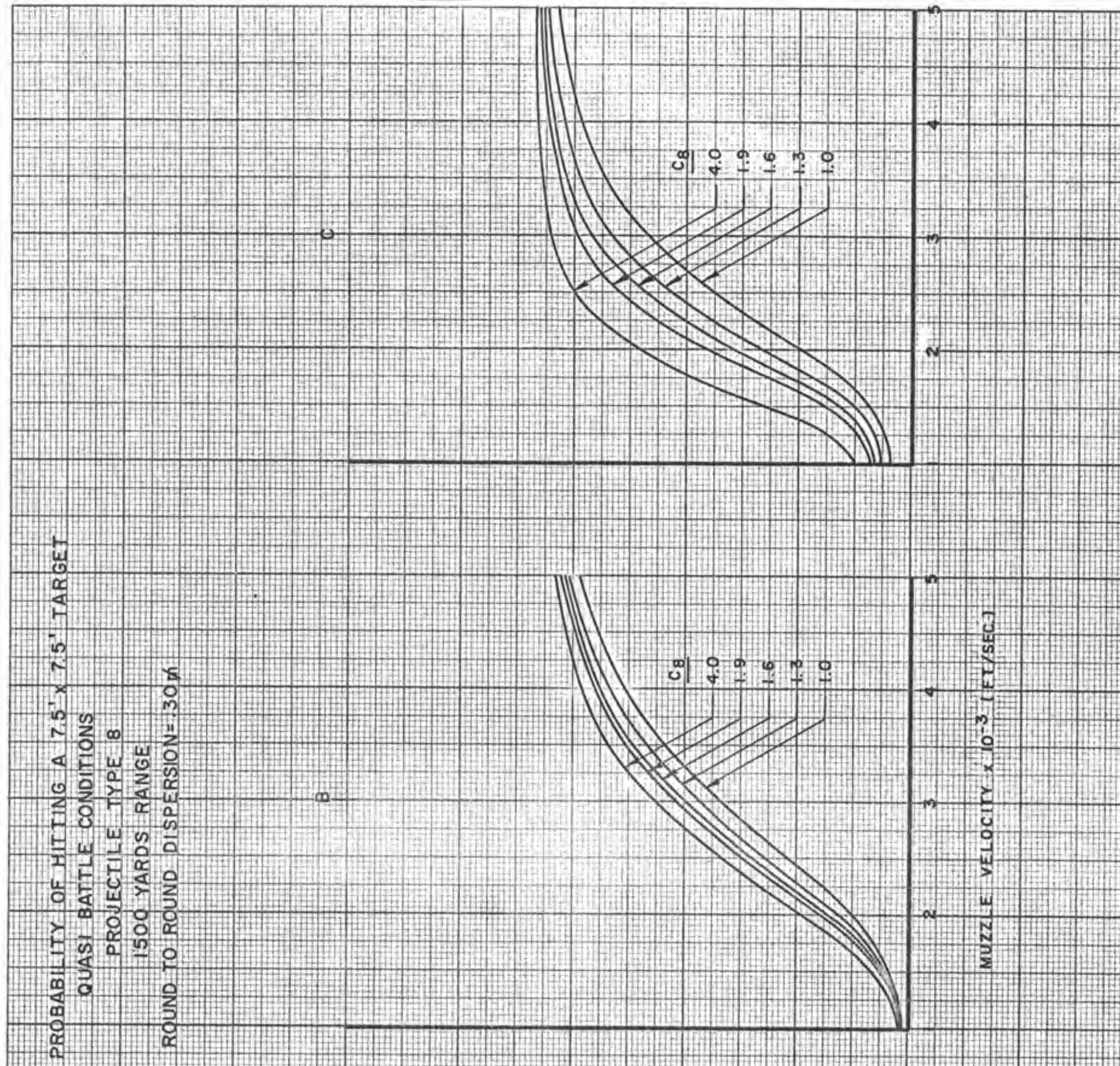


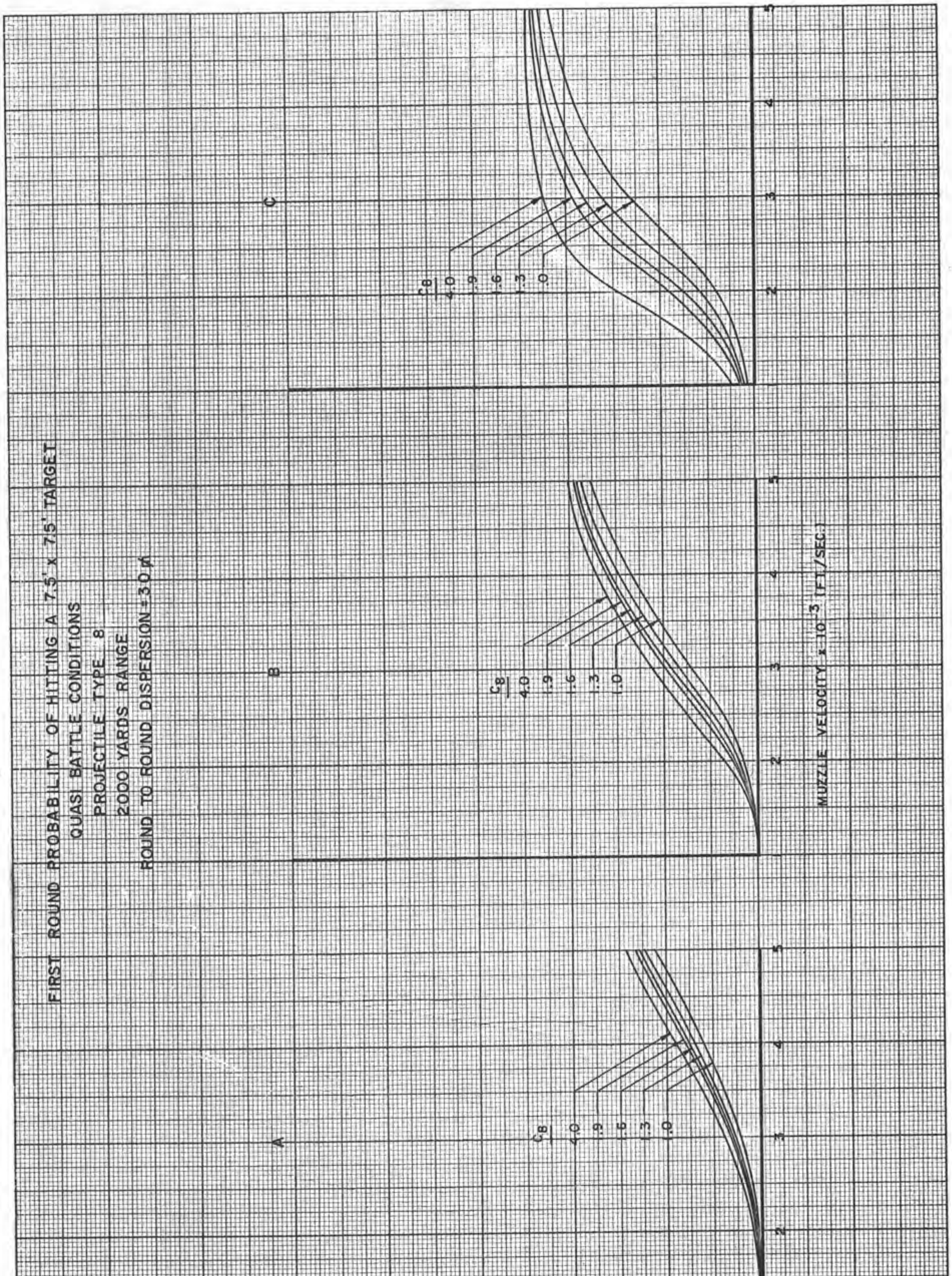


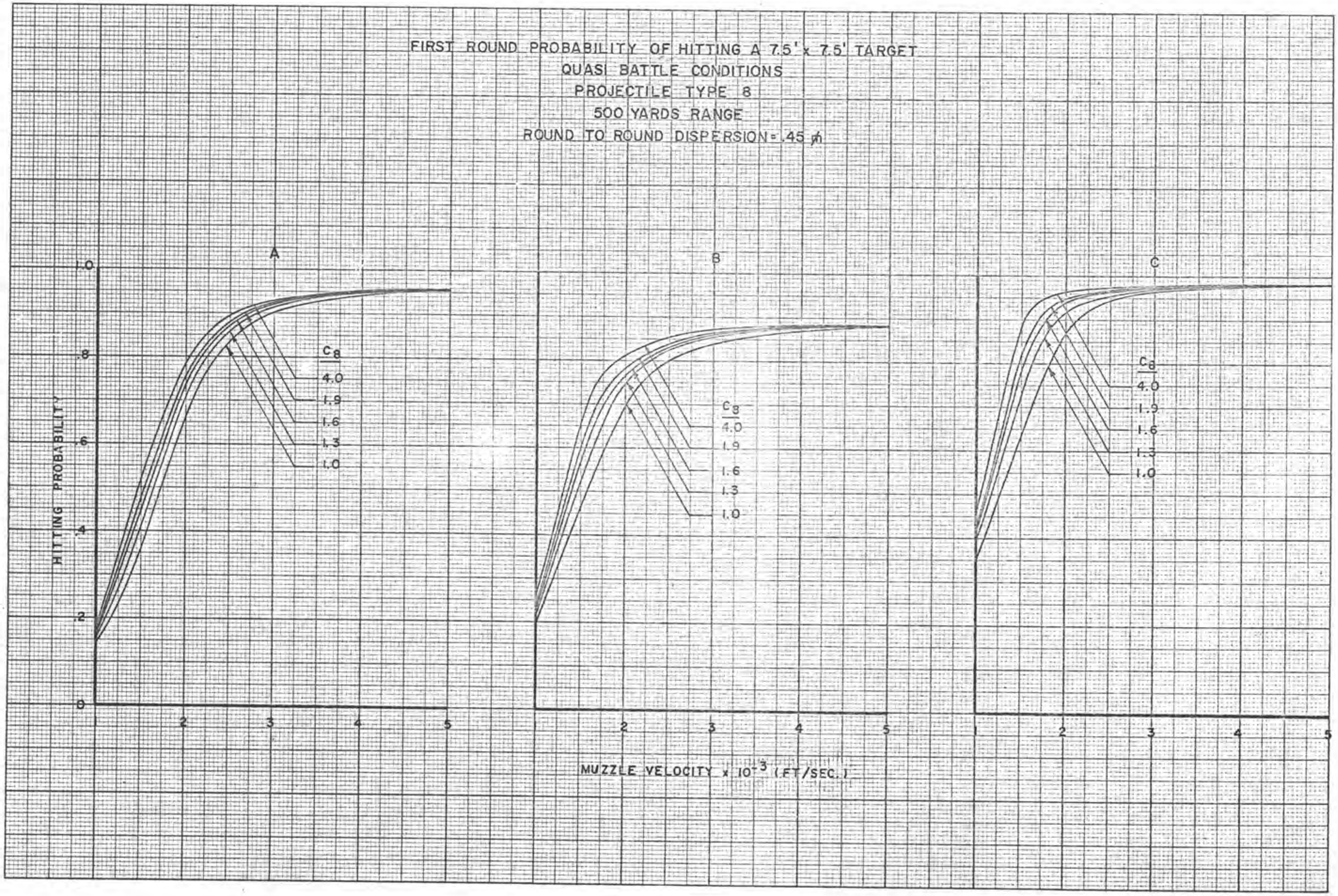
FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = 1.5 mil

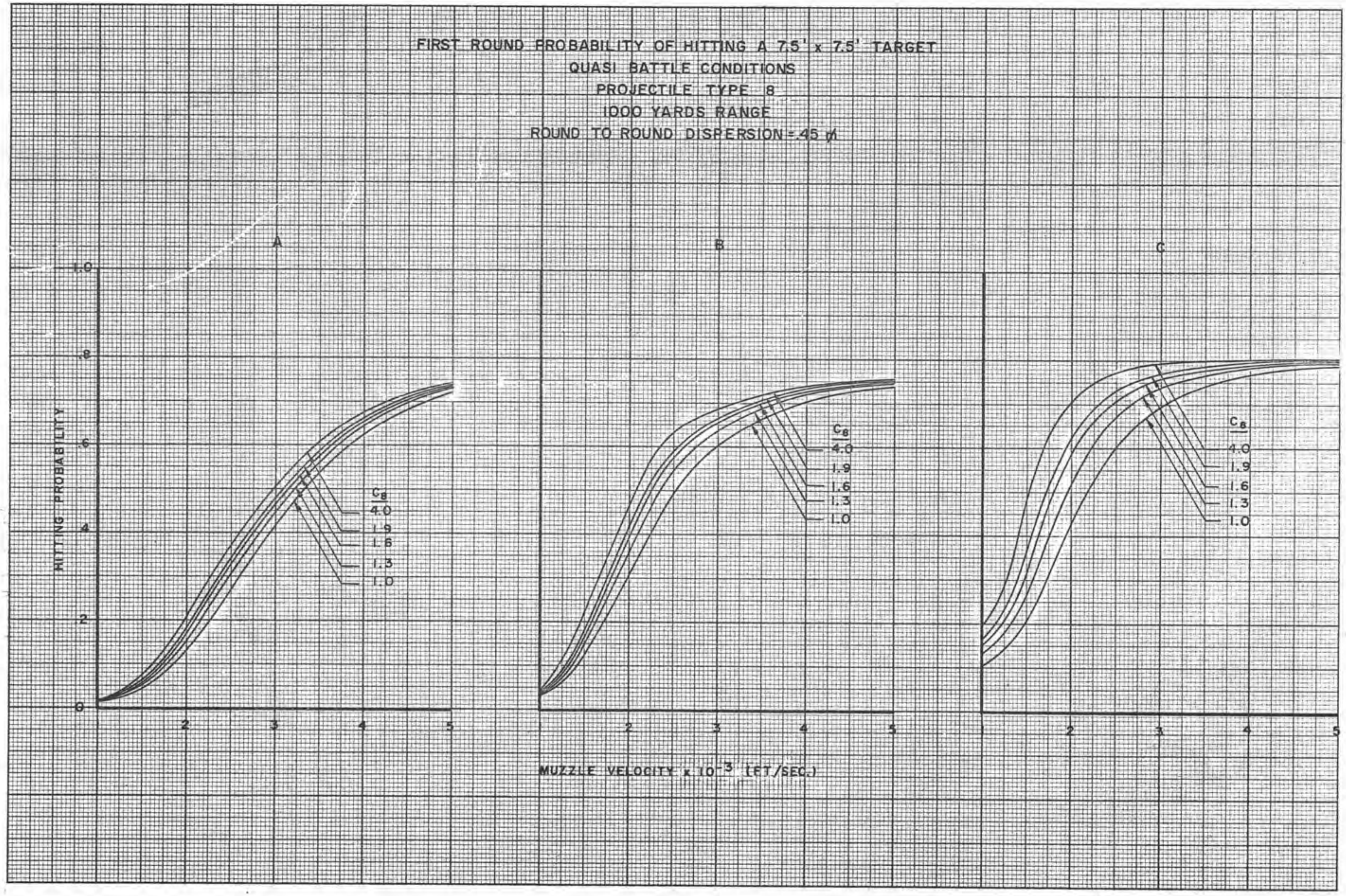

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
C_8
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)

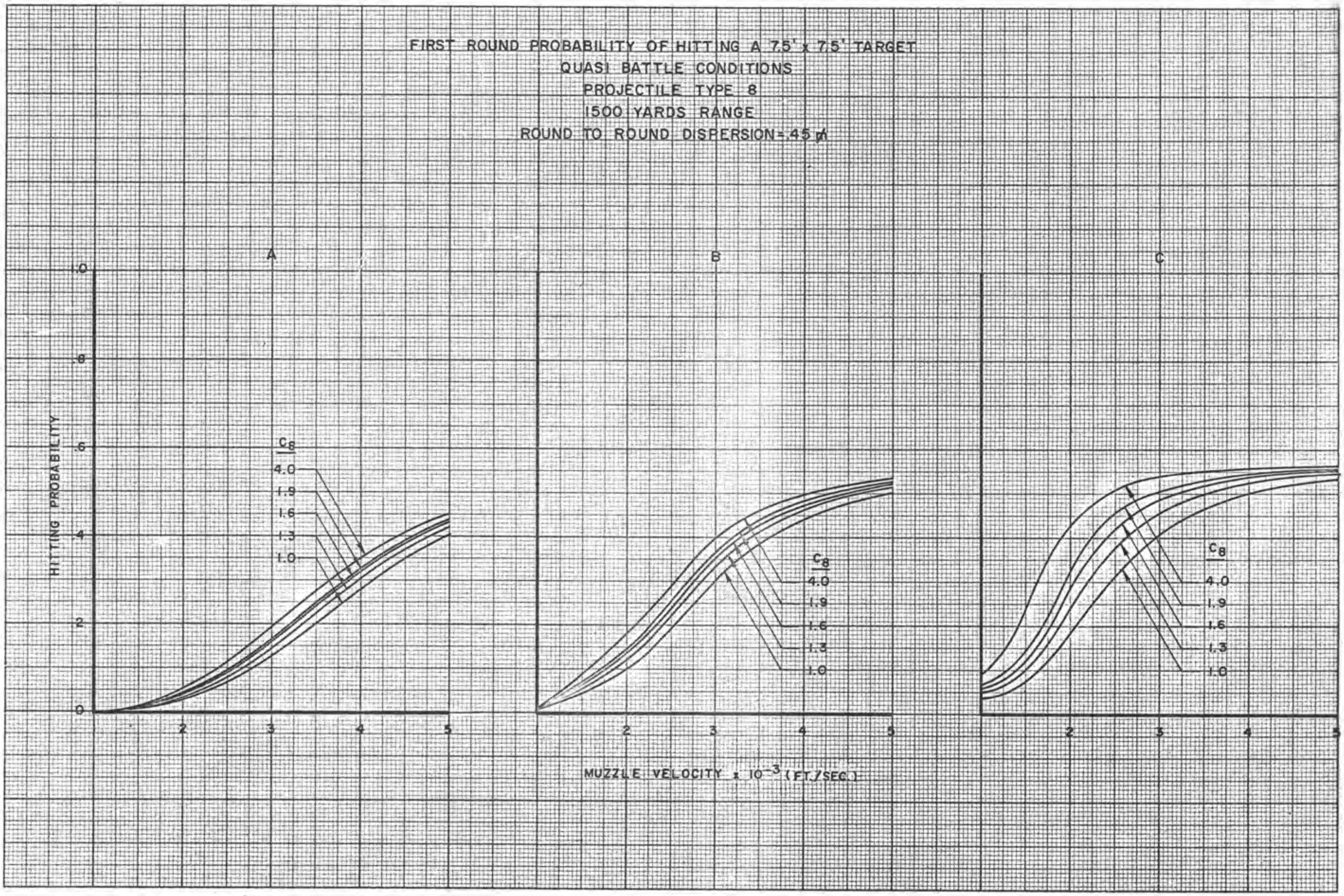

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .30 mil
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C_8
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC)

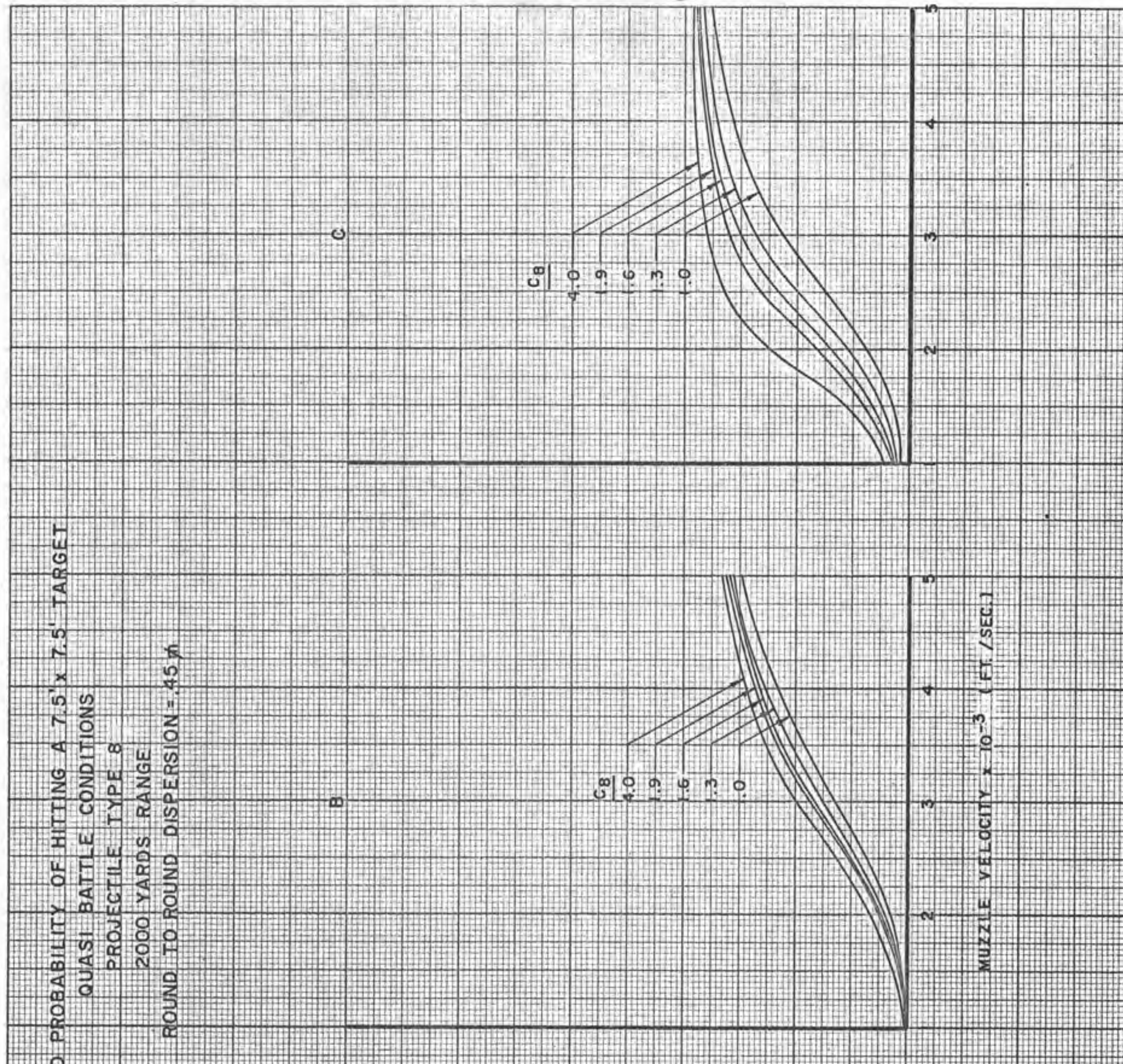

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.30 m
A
B
C
C_B
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)
2
3
4
5


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = 3.0
A
B
C
C_8
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
MUZZLE VELOCITY x 10^{-3} (FT/SEC)

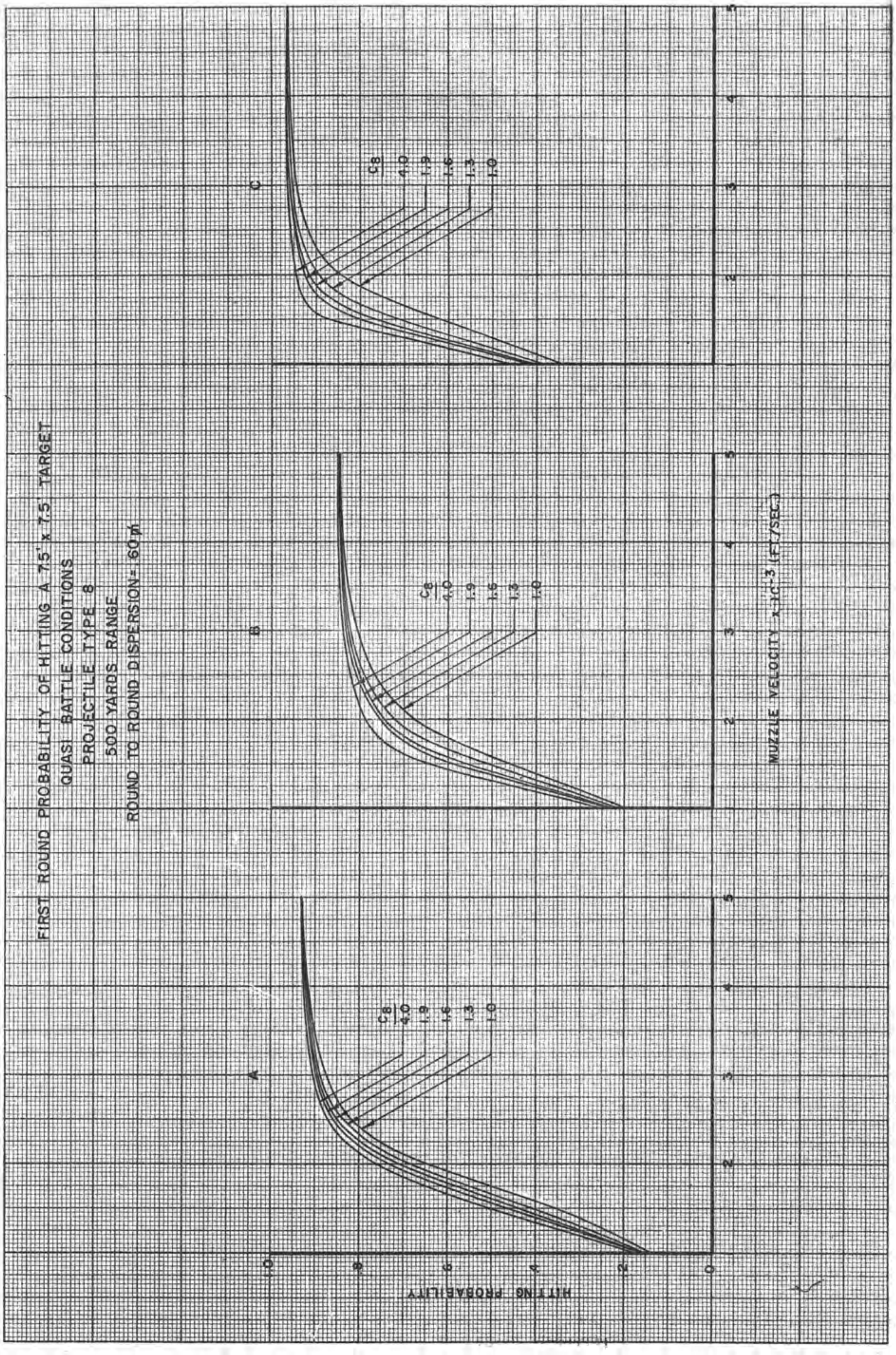

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
500 YARDS RANGE
ROUND TO ROUND DISPERSION = .45 m
A
B
C
C_8
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)

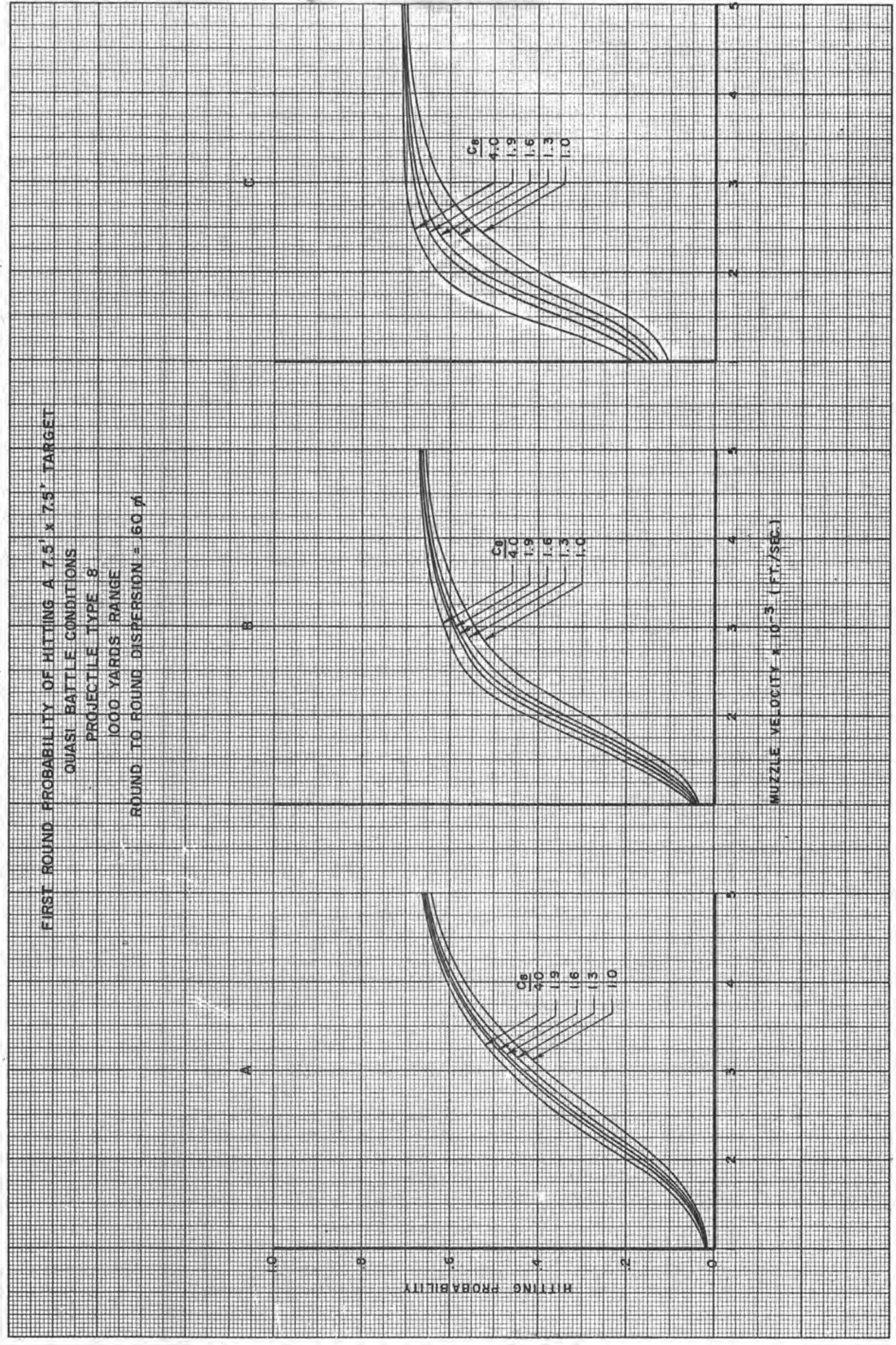

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = 45 ϕ
A
B
C
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
C_8
4.0
1.9
1.6
1.3
1.0
2
3
4
5
1
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)

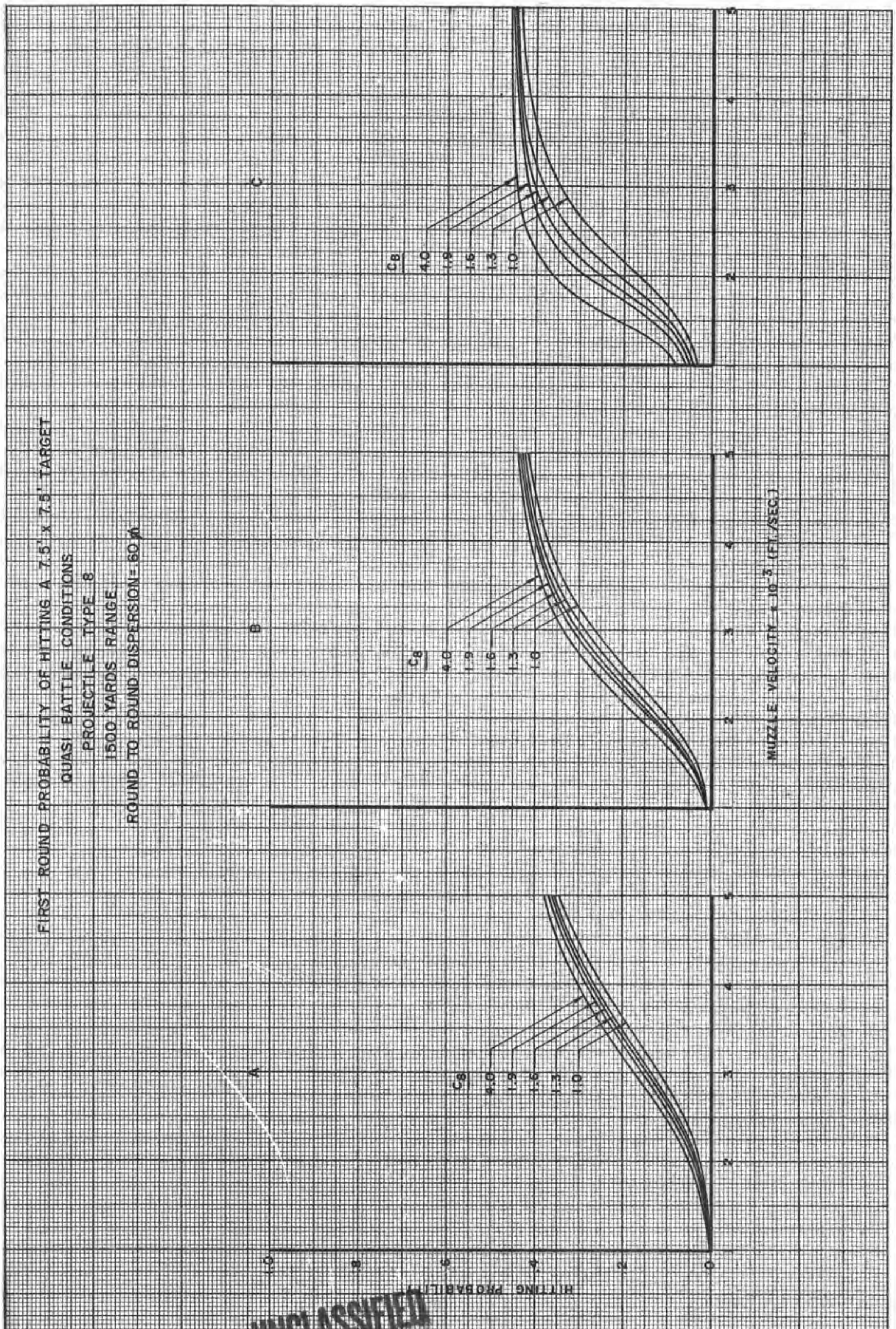

FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.45 ∕
A
B
C
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
C_8
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

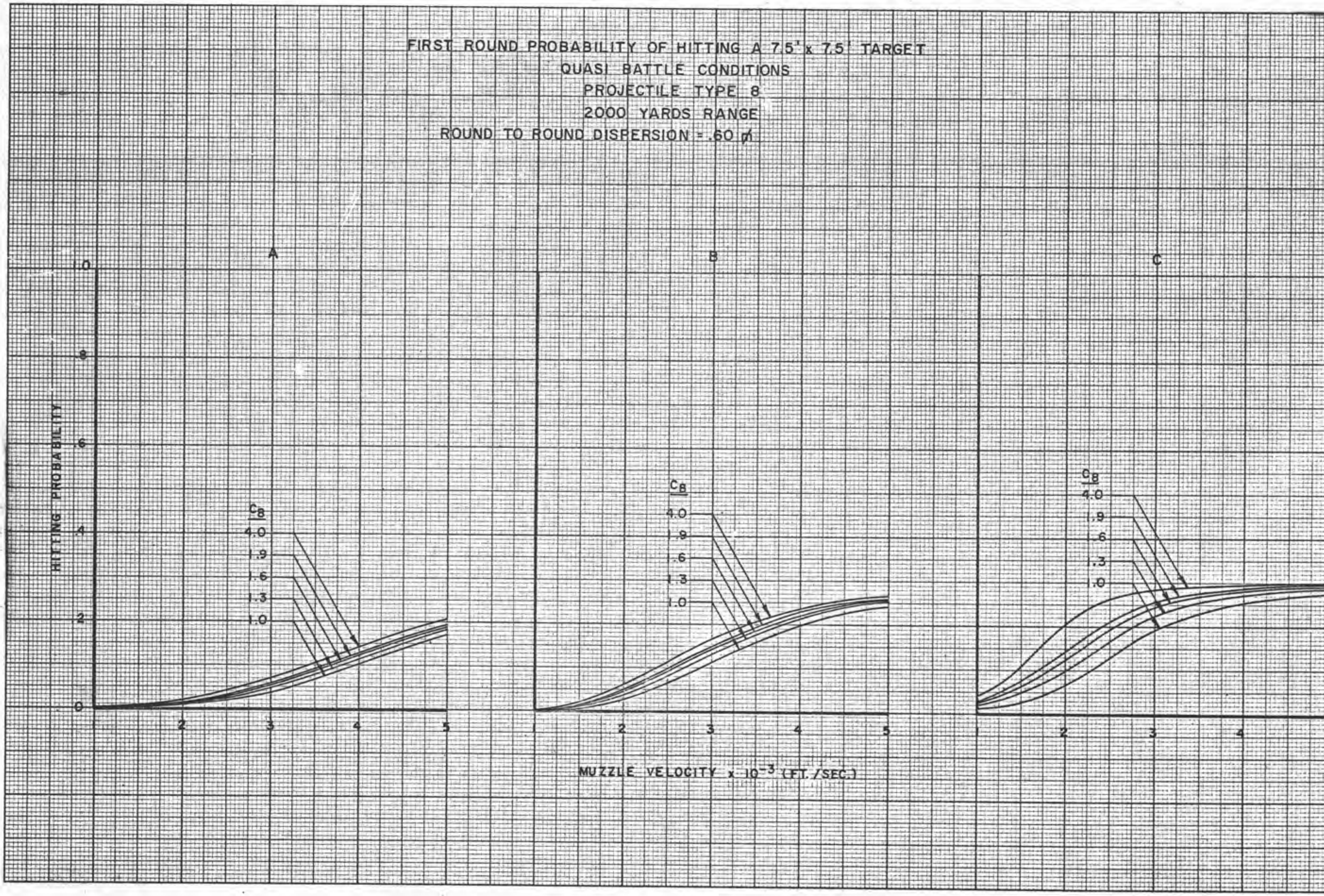


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = .45 m
A
B
C
C_B
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
1
2
3
4
5
MUZZLE VELOCITY x 10^-3 (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
500 YARDS RANGE
ROUND TO ROUND DISPERSION= 60 ₥
A
B
C
C_8
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
0
.2
.4
.6
.8
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT/SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1000 YARDS RANGE
ROUND TO ROUND DISPERSION = .60 ø
A
B
C
C_8
4.0
1.9
1.6
1.3
1.0
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
1500 YARDS RANGE
ROUND TO ROUND DISPERSION=.60 Ⓜ
A
B
C
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
C_8
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)


FIRST ROUND PROBABILITY OF HITTING A 7.5' x 7.5' TARGET
QUASI BATTLE CONDITIONS
PROJECTILE TYPE 8
2000 YARDS RANGE
ROUND TO ROUND DISPERSION = .60 ∅
A
B
C
HITTING PROBABILITY
1.0
.8
.6
.4
.2
0
C_B
4.0
1.9
1.6
1.3
1.0
2
3
4
5
MUZZLE VELOCITY x 10^{-3} (FT./SEC.)

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THE EFFECT OF SYSTEM DESIGN CHARACTERISTICS ON FIRST ROUND HITTING PROBABILITY OF TANK FIRED PROJECTILES

E. C. Christman

BRLM Report No. 1192 February 1959

DA Proj No. 503-04-004, ORD Proj No. TB3-1224

[redacted]

UNCLASSIFIED

Tanks - Armament
Tanks - Fire control system
Hitting probability - Tank armament

Graphs showing the first round probability of hitting a stationary vertical 7.5' by 7.5' target under quasi-combat conditions are presented for a wide range of conventional tank armament system characteristics. These results provide a way of rapidly estimating the first round hitting capabilities of various systems and are used in studying the relative effect of various projectile and fire control design parameters.

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